Sheet Metal Industries

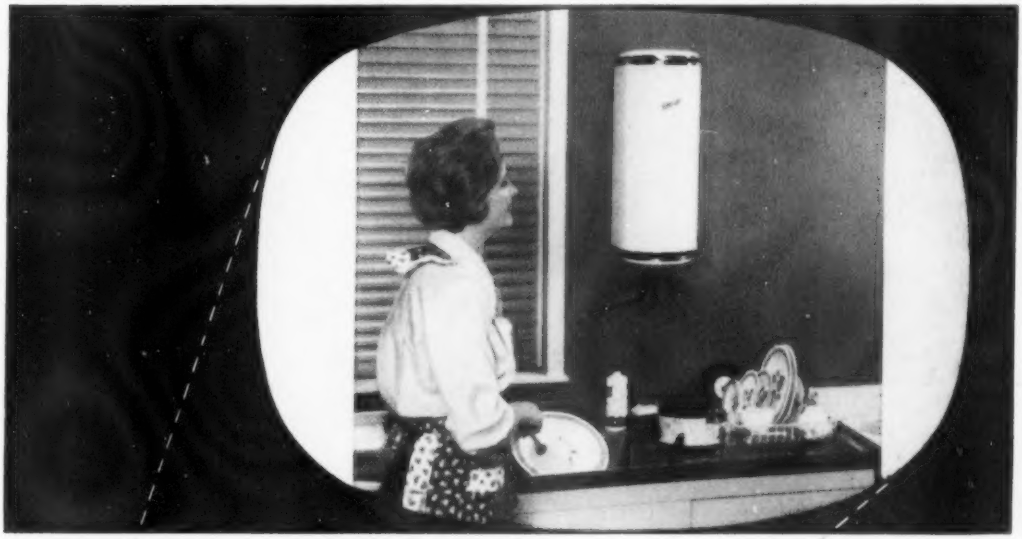
The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

VOL. 38 : No. 414 OCTOBER 1961 PRICE 2/6

Editorial Contents: 701, 703 **Classified Advertisements: 111 to 114**


COWLISHAW
WALKER

☛ STELVETITE–
plastic bonded to steel has put a new face on the SADIA TWO-PLUS Water Heater



The use of Stelvetite in the manufacture of the Sadia Two-Plus provides a perfect example of the economy it achieves. Aidas Electric Ltd. decided to open a satellite factory at Salisbury to make this popular heater. The factory was planned around the exclusive use of Stelvetite for casings, thus eliminating the need for a paint shop because Stelvetite has a finished surface. As a result capital costs were cut by 17½% and production started three months earlier than would otherwise have been possible. This economy is additional to the cost and time saved in actual manufacture. The P.V.C. surface of Stelvetite is impervious to superficial knocks, chips and scratches, yet it is decorative, heat resistant, an insulation and its colour holds fast.

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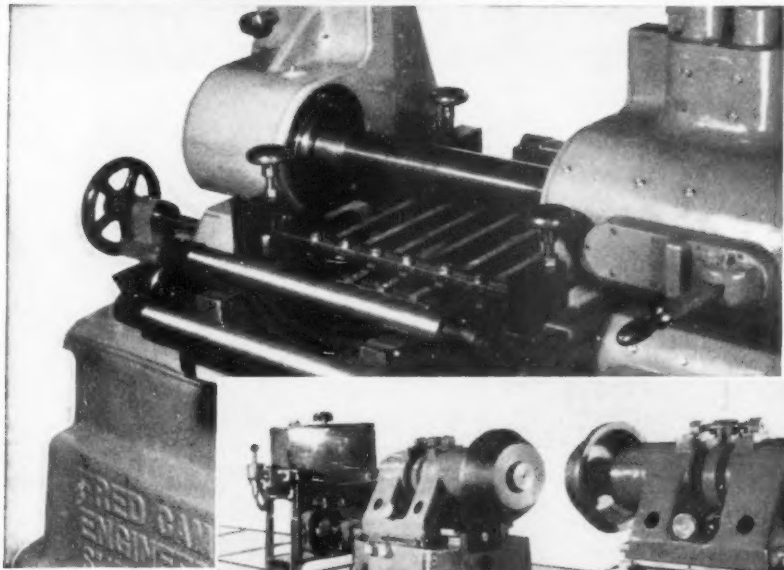

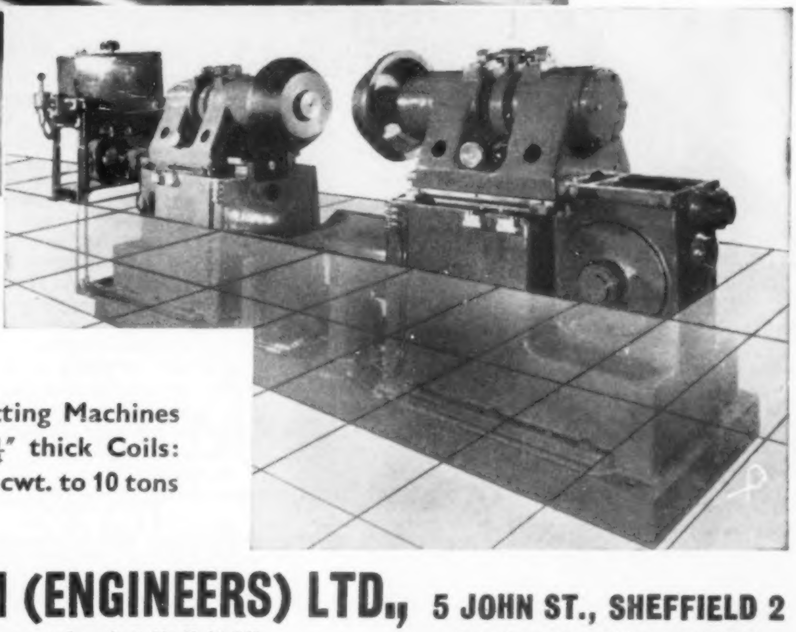

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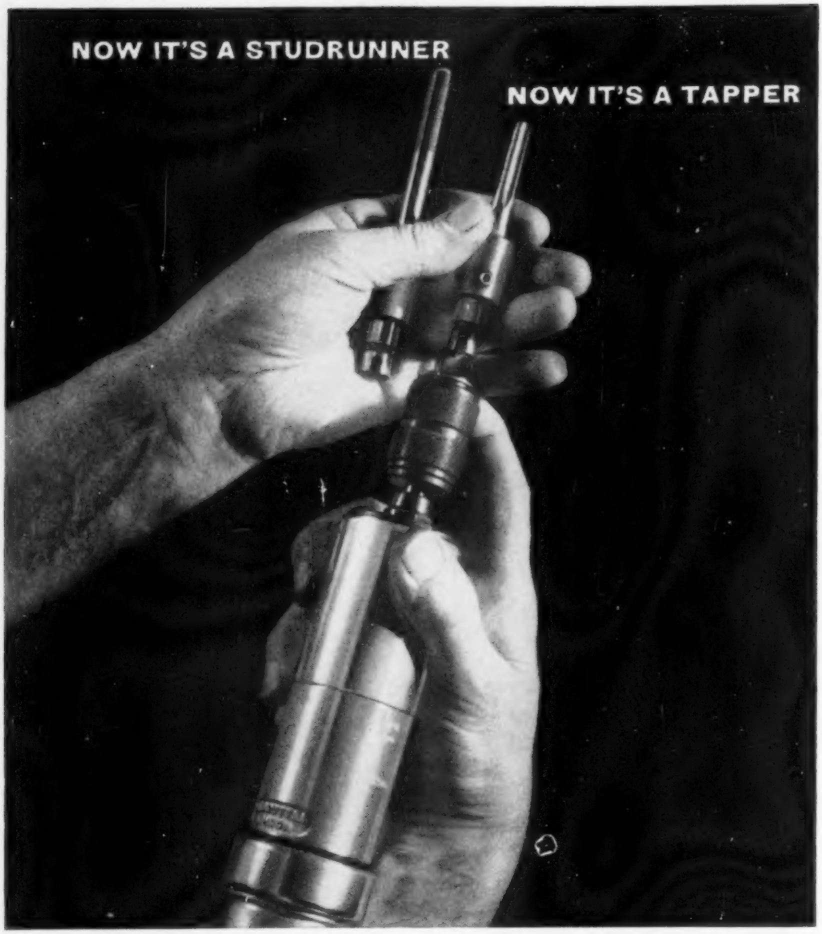

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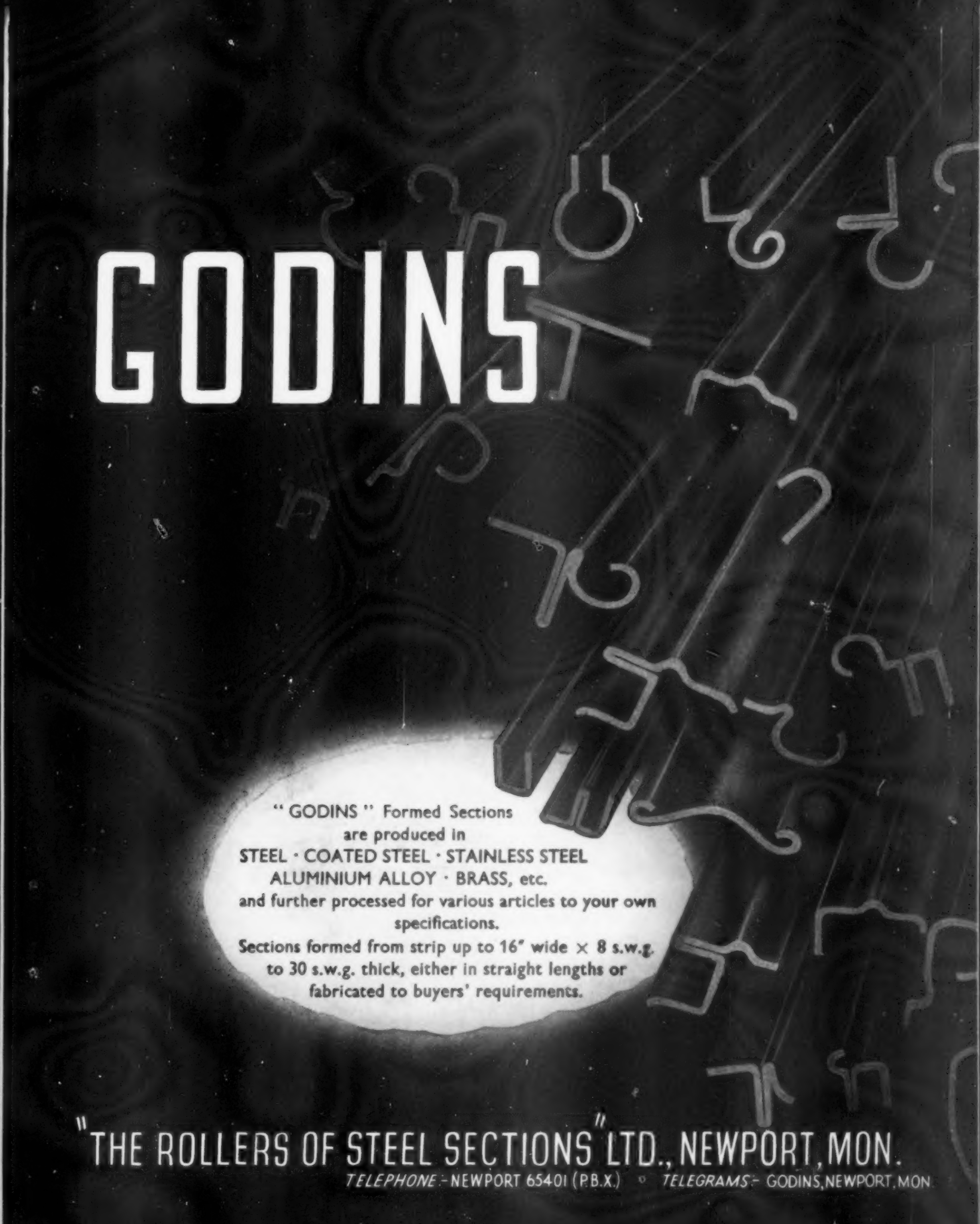
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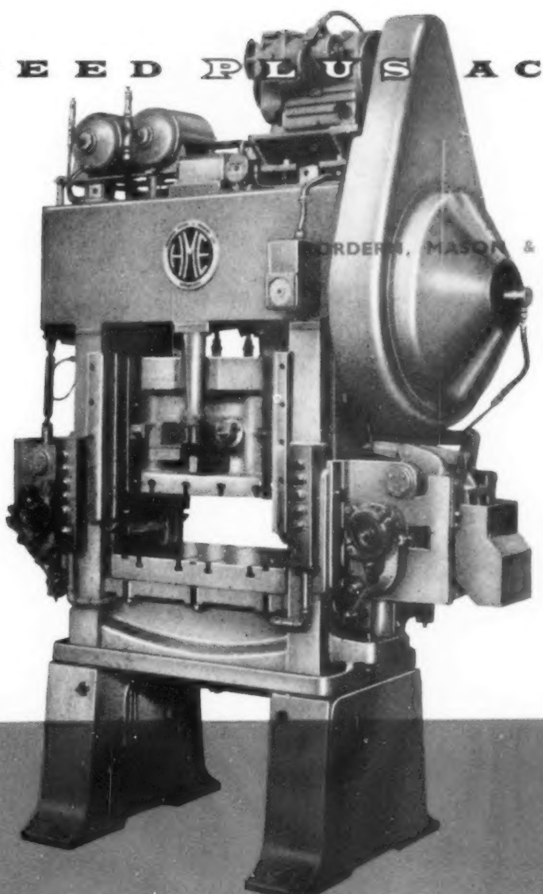

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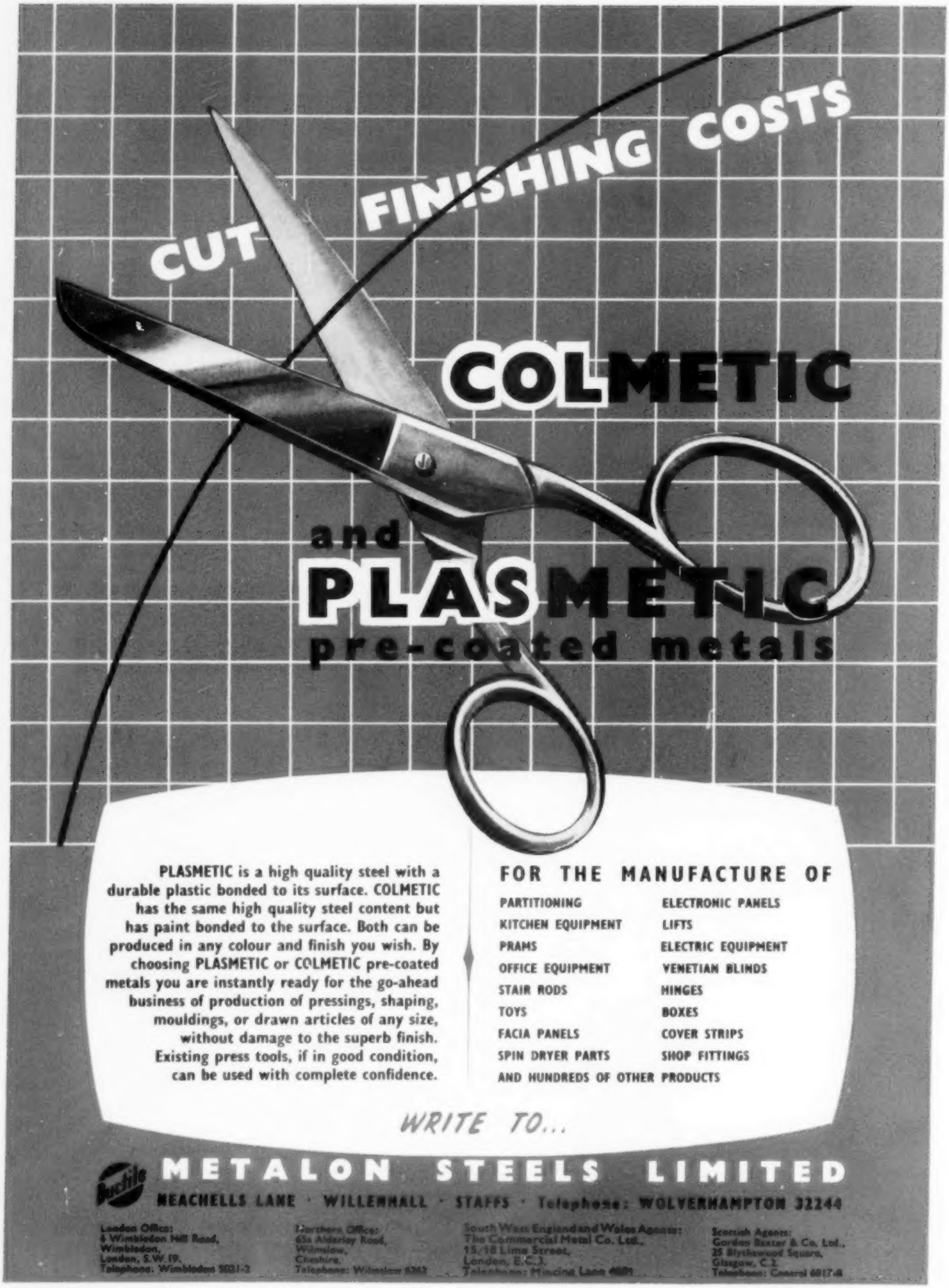
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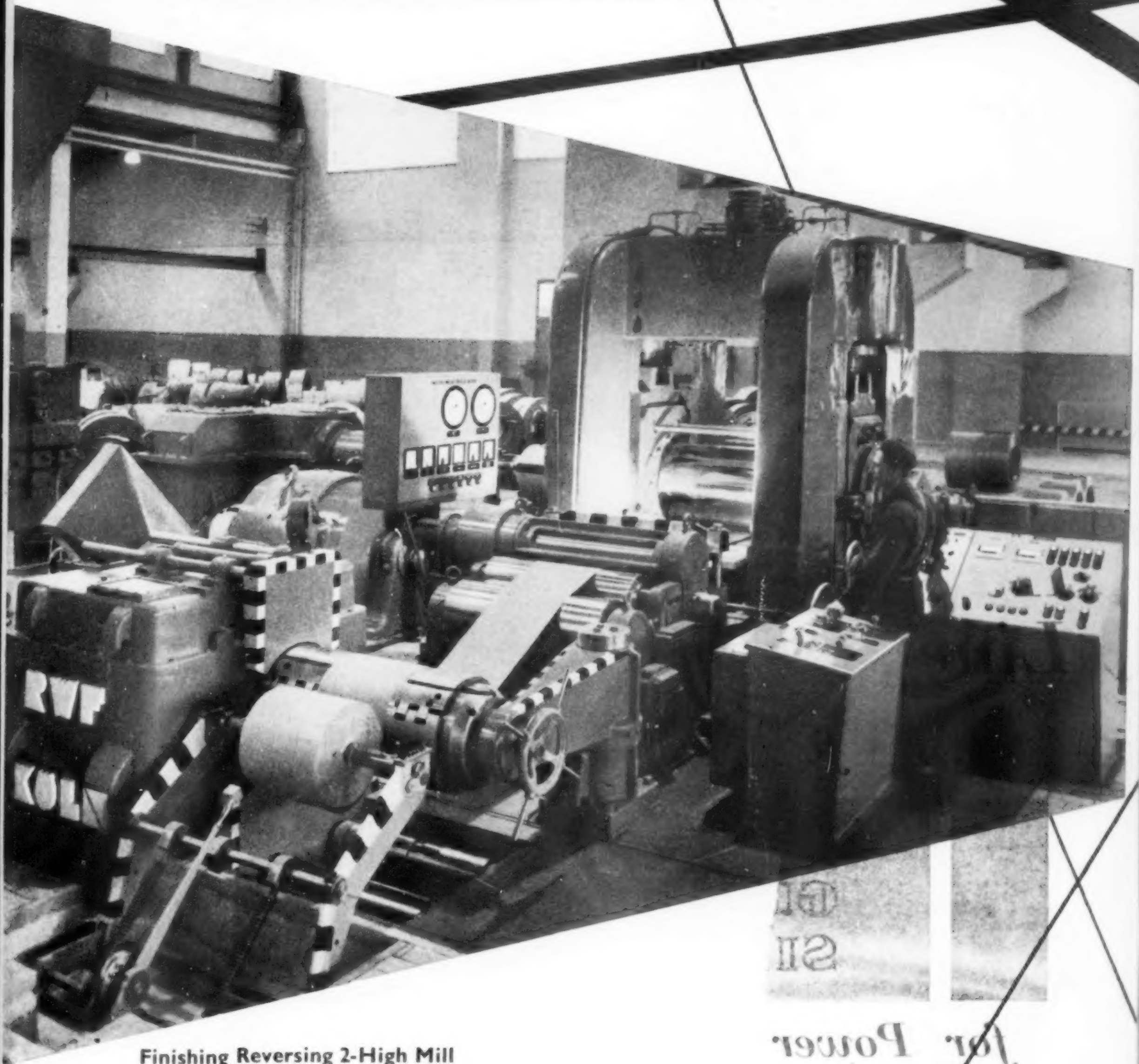
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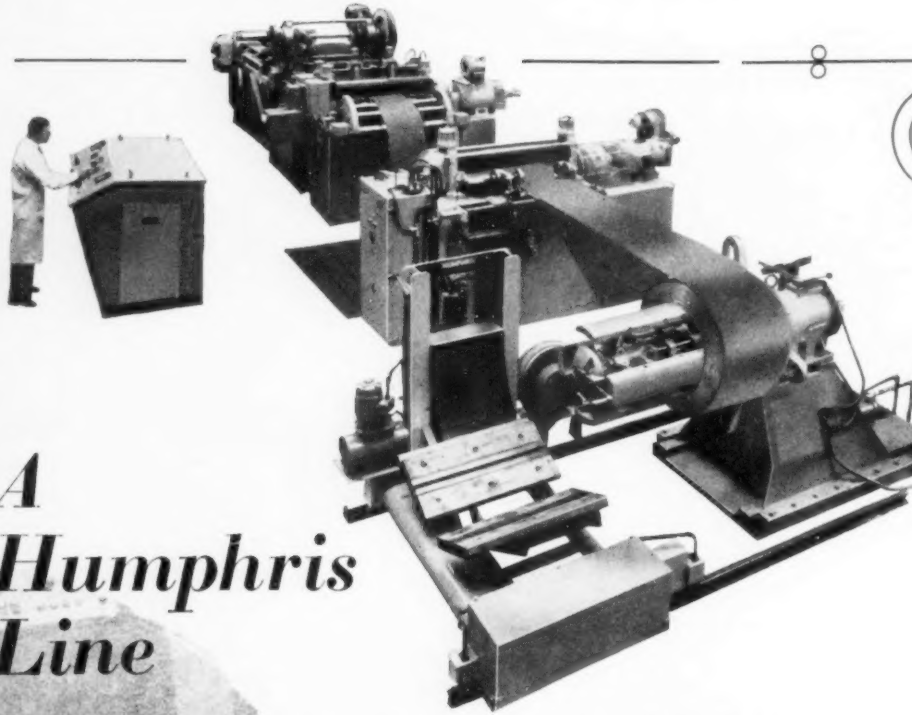

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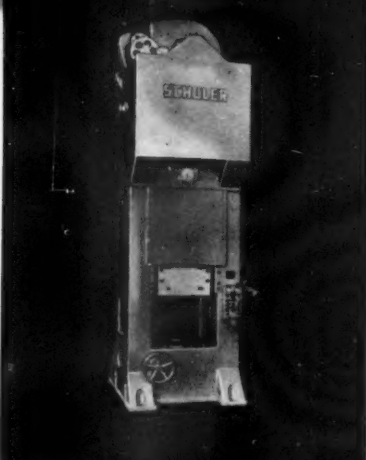
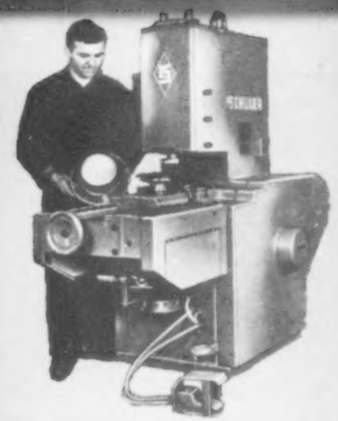


Wide Frame Toggle Drawing Presses



Notching Machines in 5 sizes

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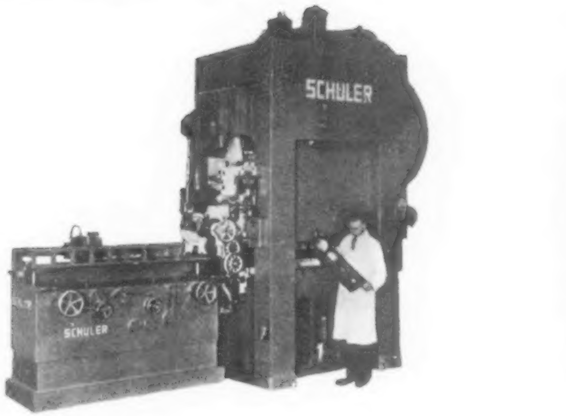

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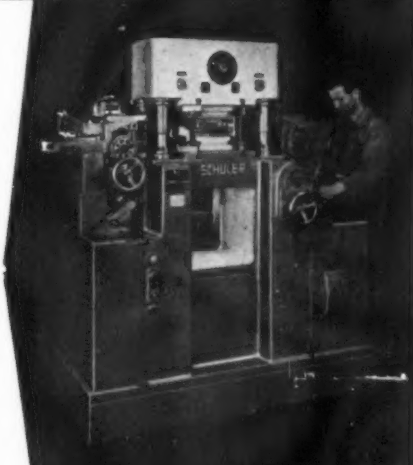

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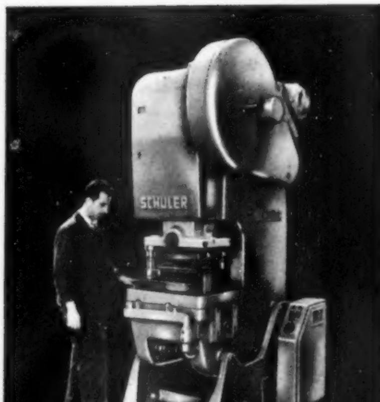
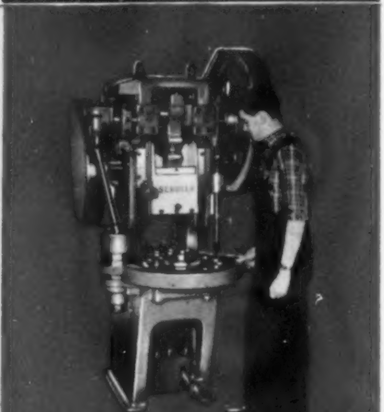
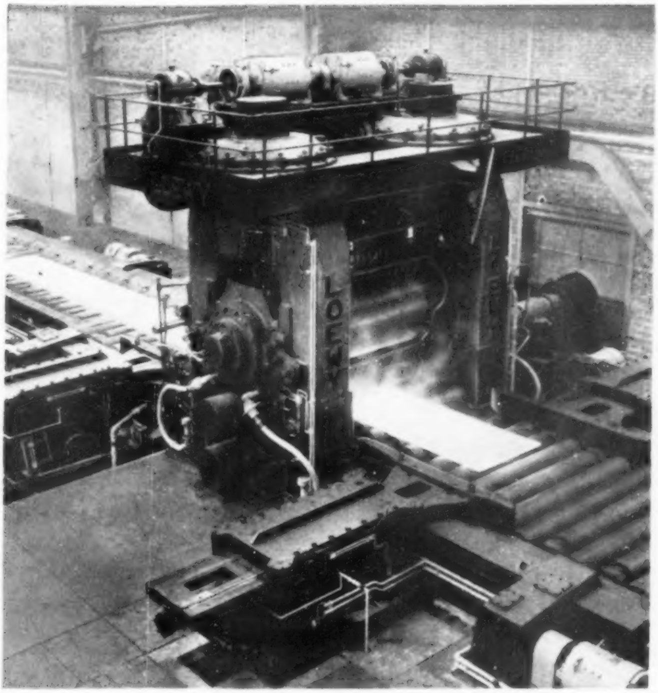


C-Frame Power Presses

Transfer Presses



Dial Feed Presses



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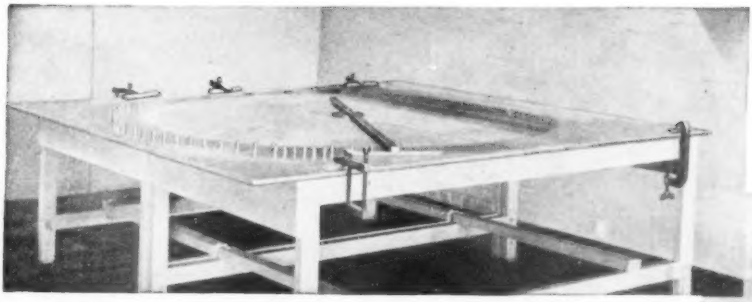

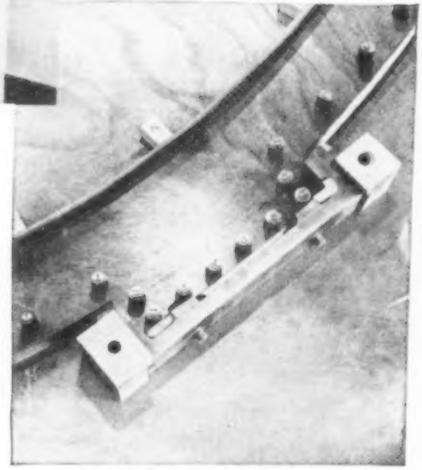

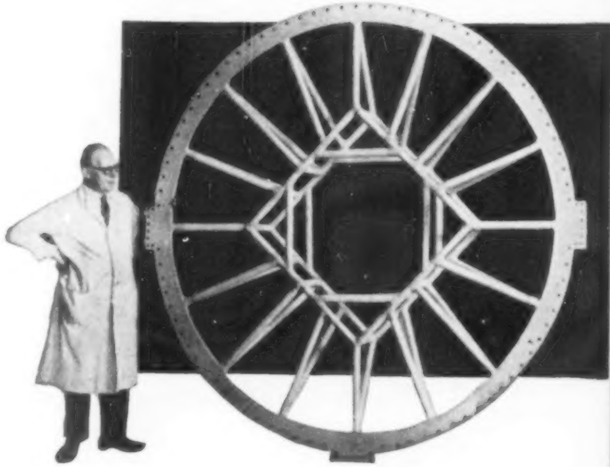

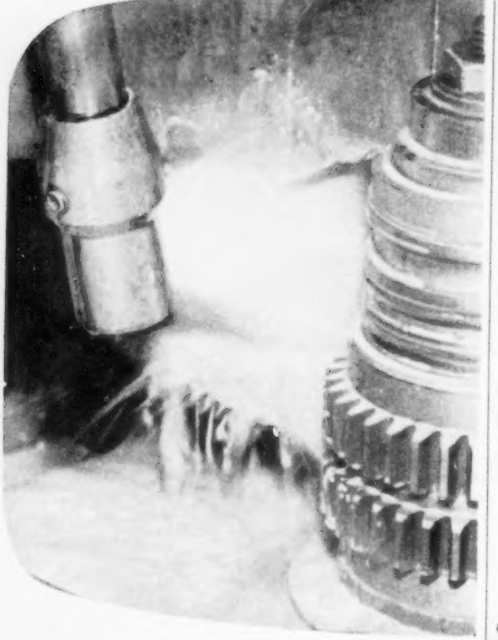

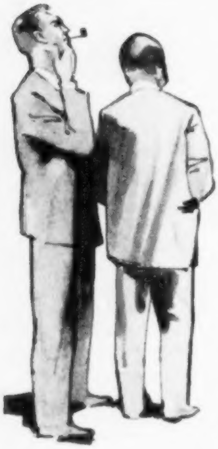

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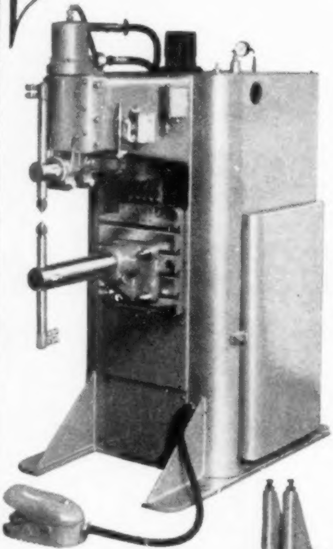

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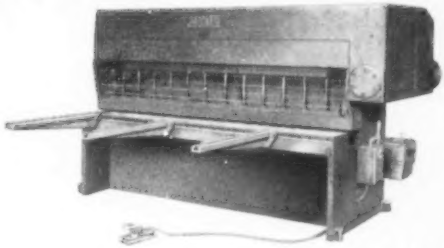

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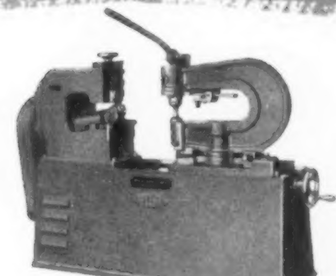

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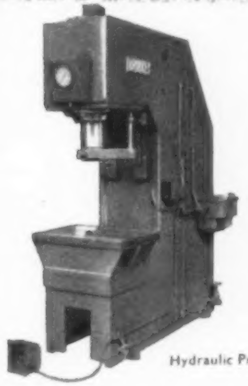

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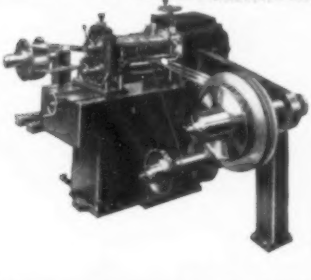

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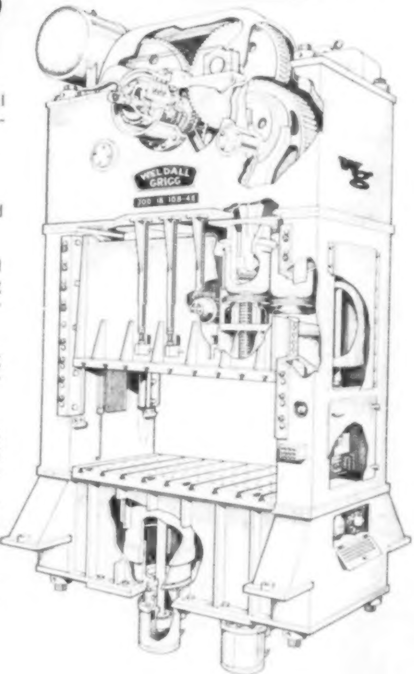

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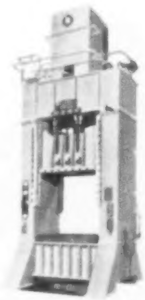

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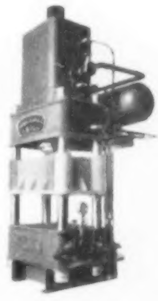

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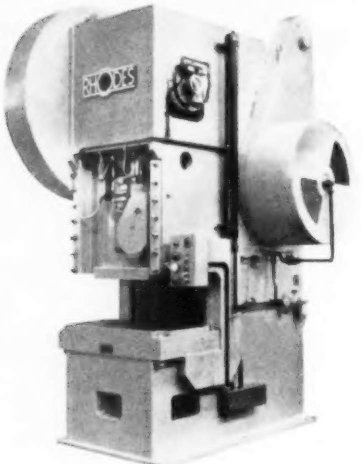
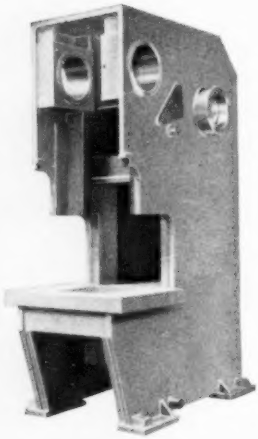
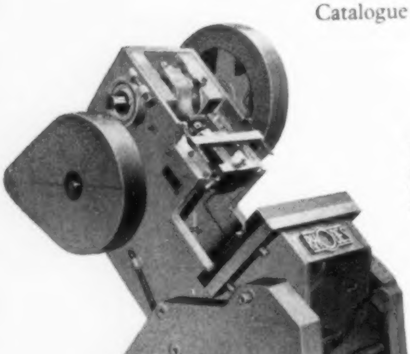
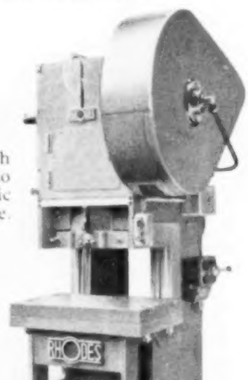




The sturdy fabricated one-piece steel frame of Rhodes C-Frame Presses is only one aspect of their merits—full details of all their constructional and operational features are contained in Catalogue RFP-60.



Press with friction clutch control — available also with electro-pneumatic friction clutch and brake.



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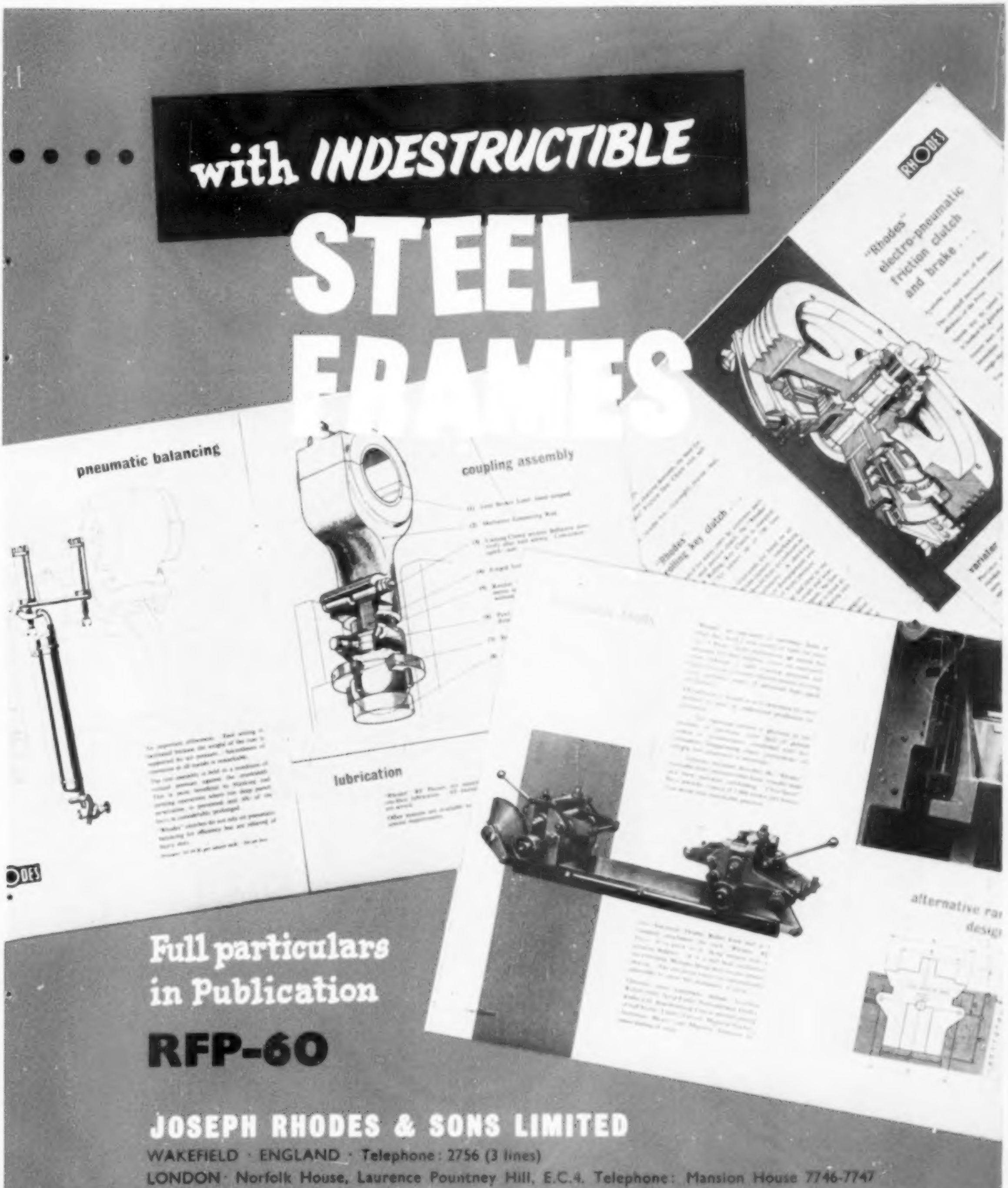
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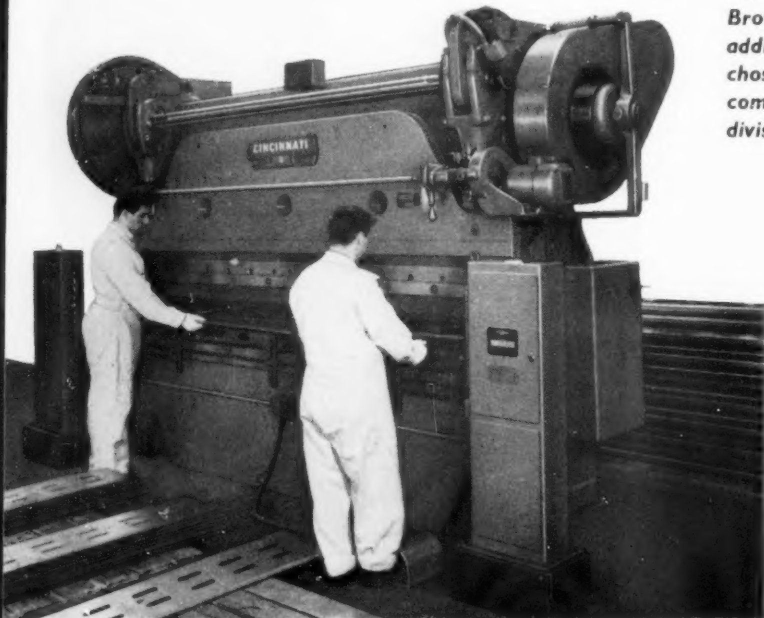

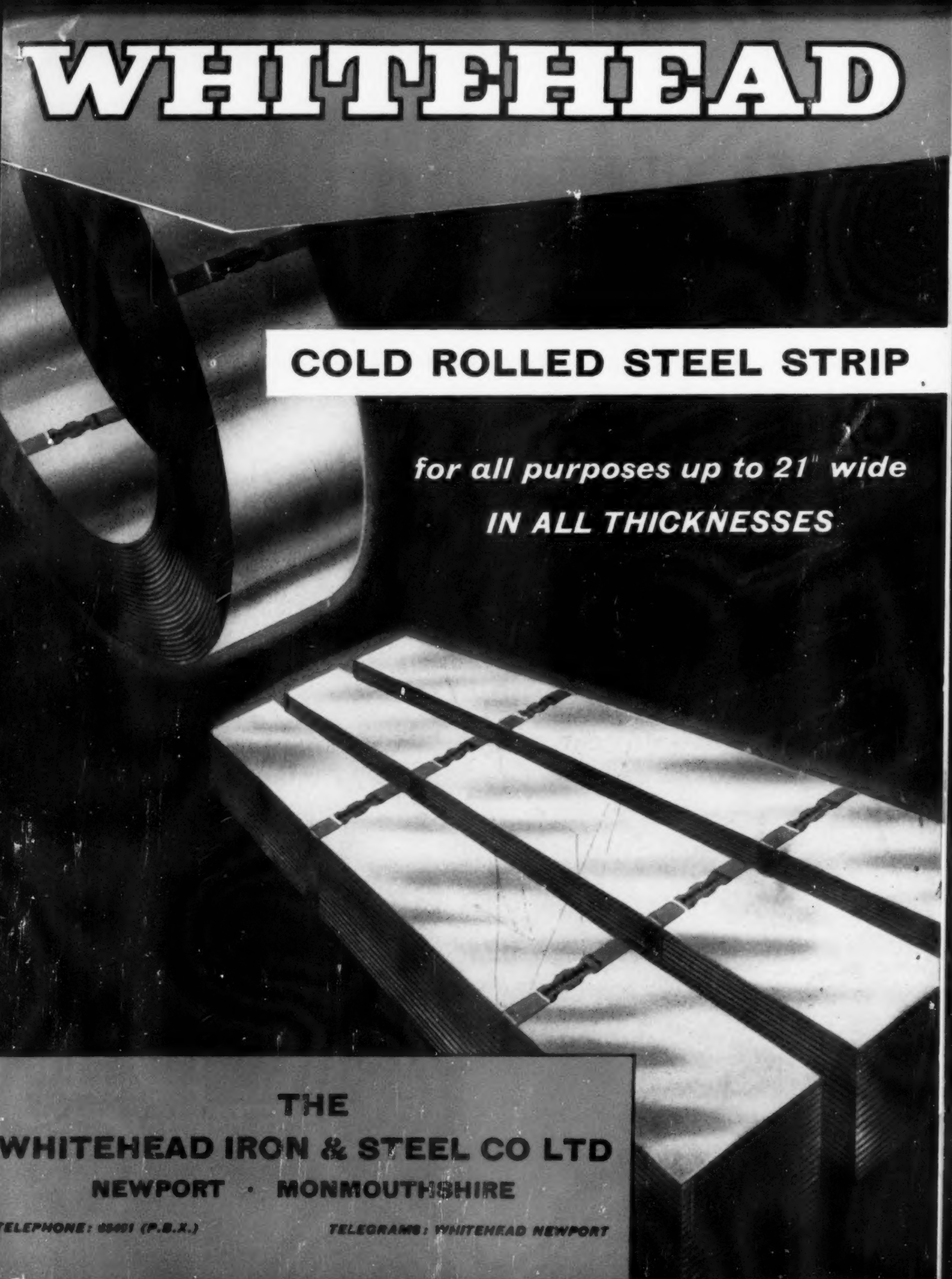
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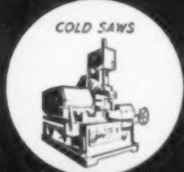

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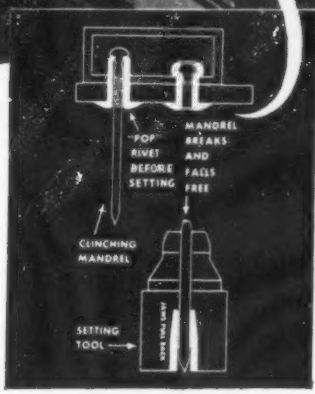

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Illustrated: Clothing locker installation by Steel Equipment Co. Ltd., West Bromwich, Staffs.

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RIVETS

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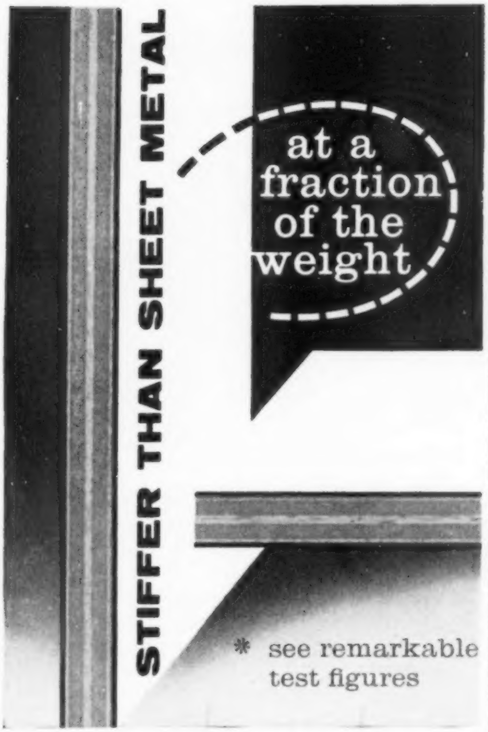

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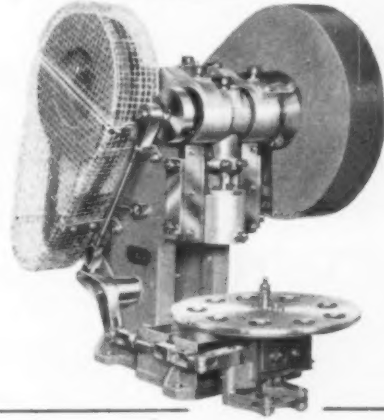

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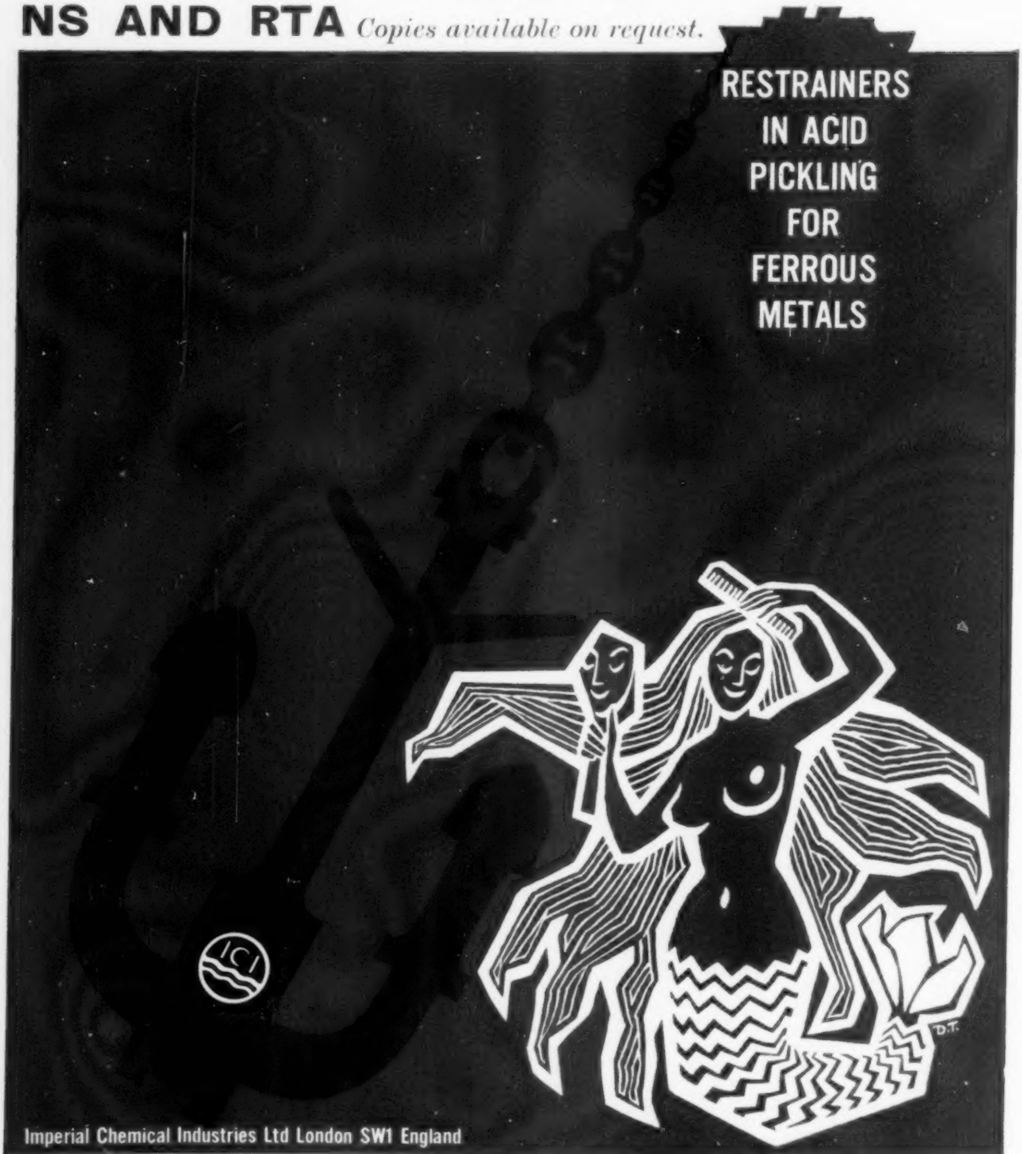

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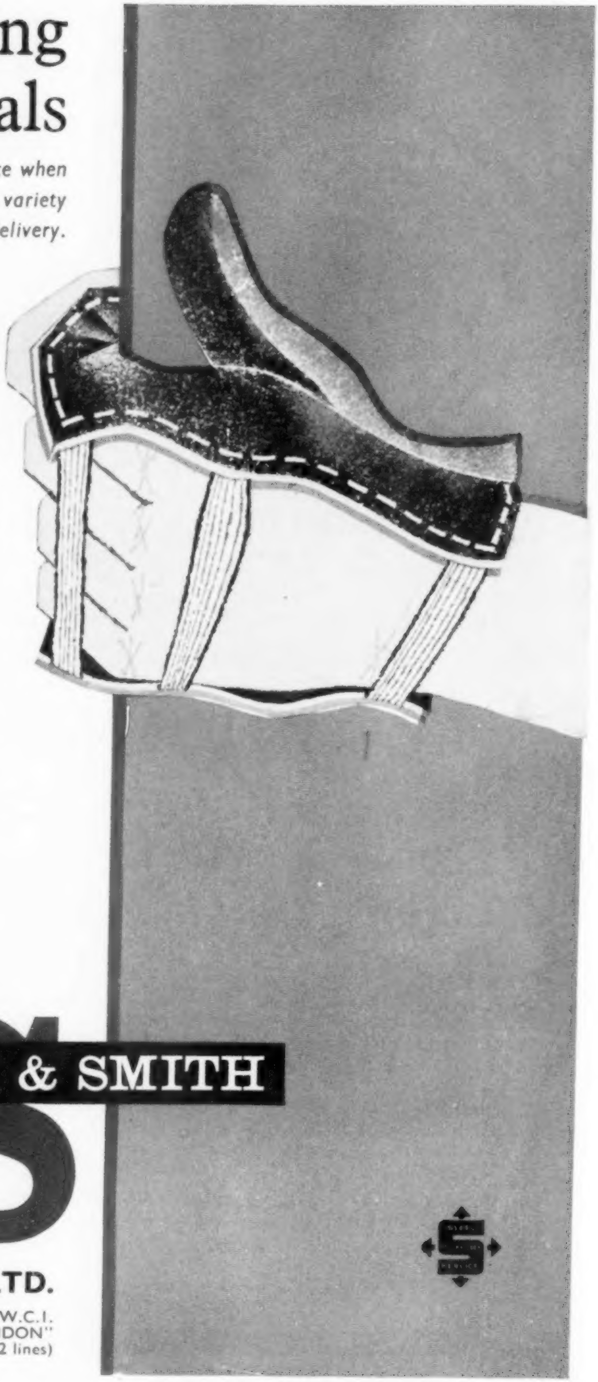

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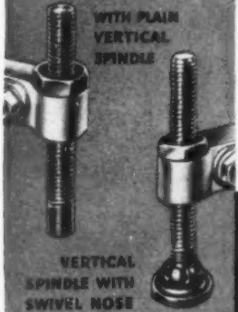

Low overall height is a feature of this Clamp. It is only 2⅞" high in the clamped position allowing cutters and arbours to travel over the Clamp for milling, grinding operations, etc. 3 types of spindles are available.

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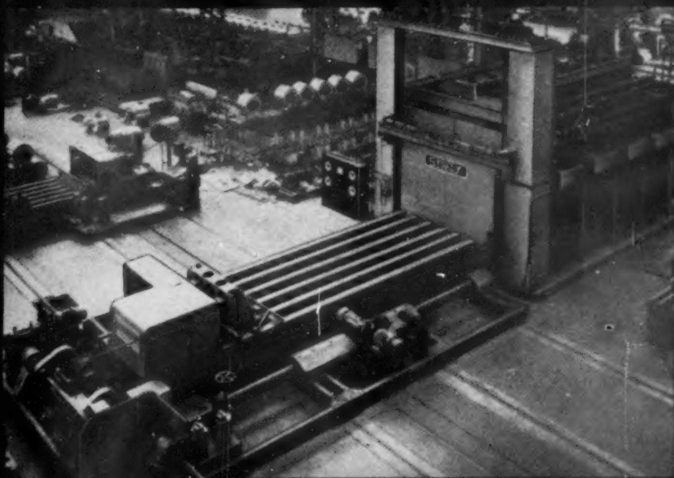

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STORDY ENGINEERING LIMITED

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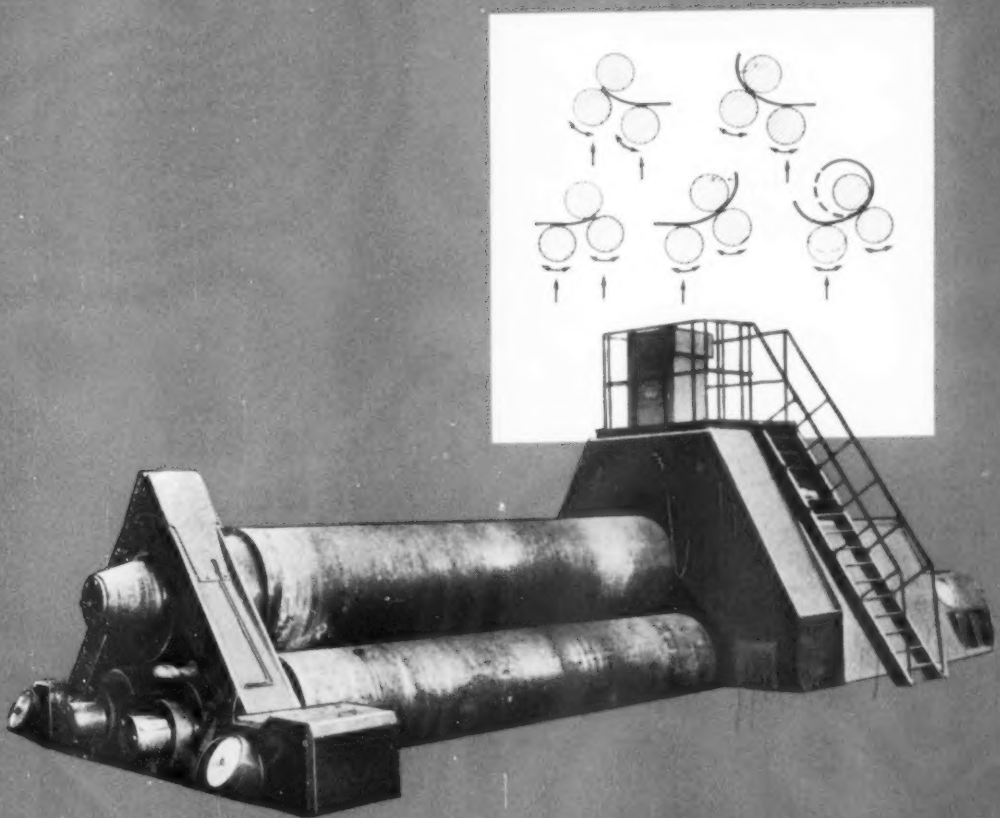

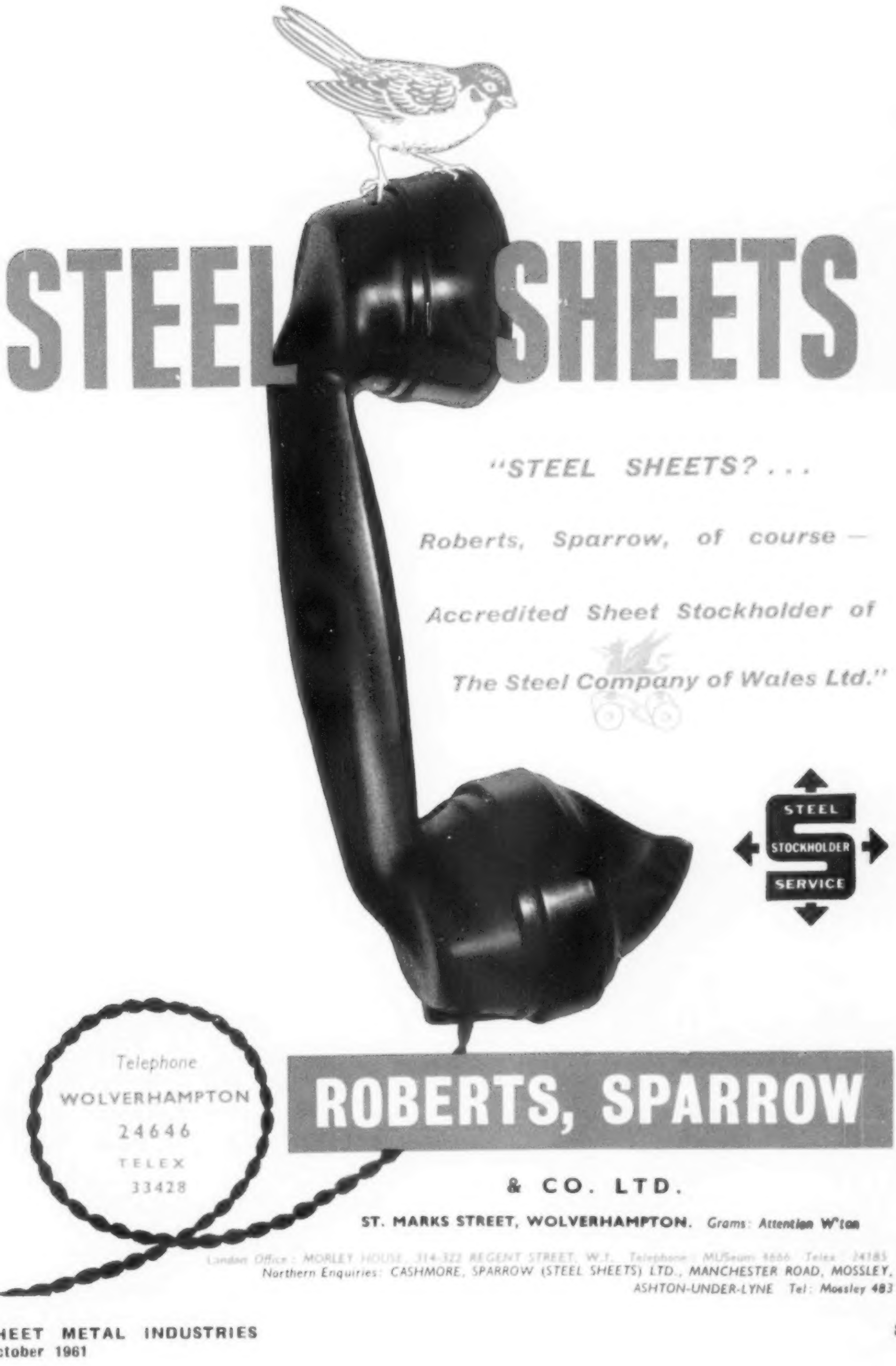

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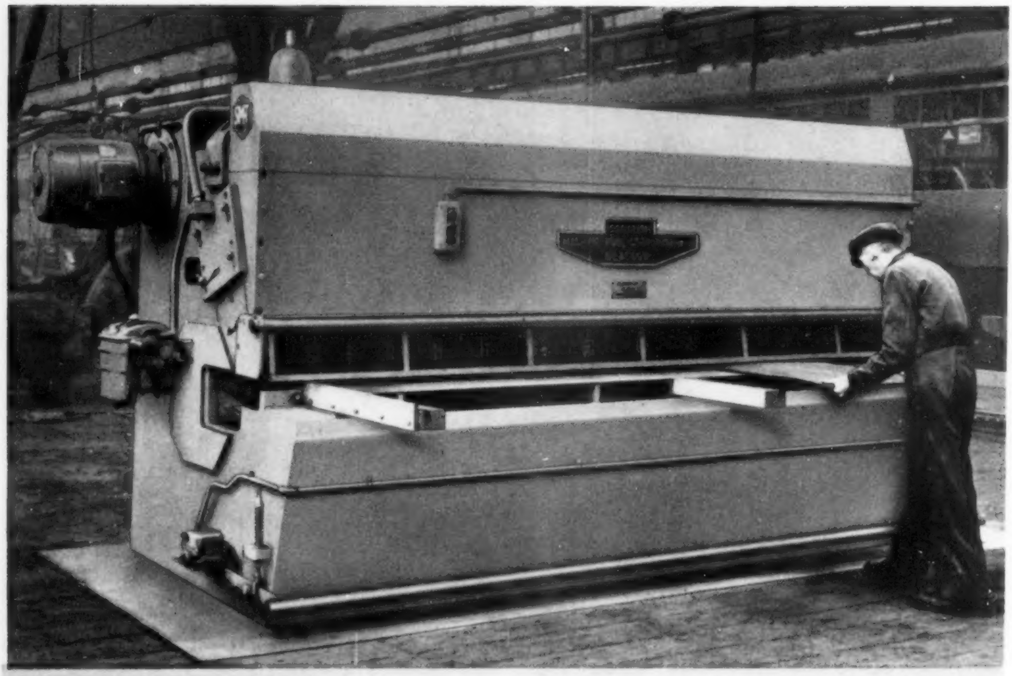

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Our Guillotines of this design are proving extremely popular and they have many advantages over mechanical and other types of hydraulic guillotines. We ourselves continue to manufacture mechanical guillotines and can therefore recommend them when our customers' needs are met more adequately by that type of drive. For the great majority of applications, however, the hydraulic machine is to be preferred.

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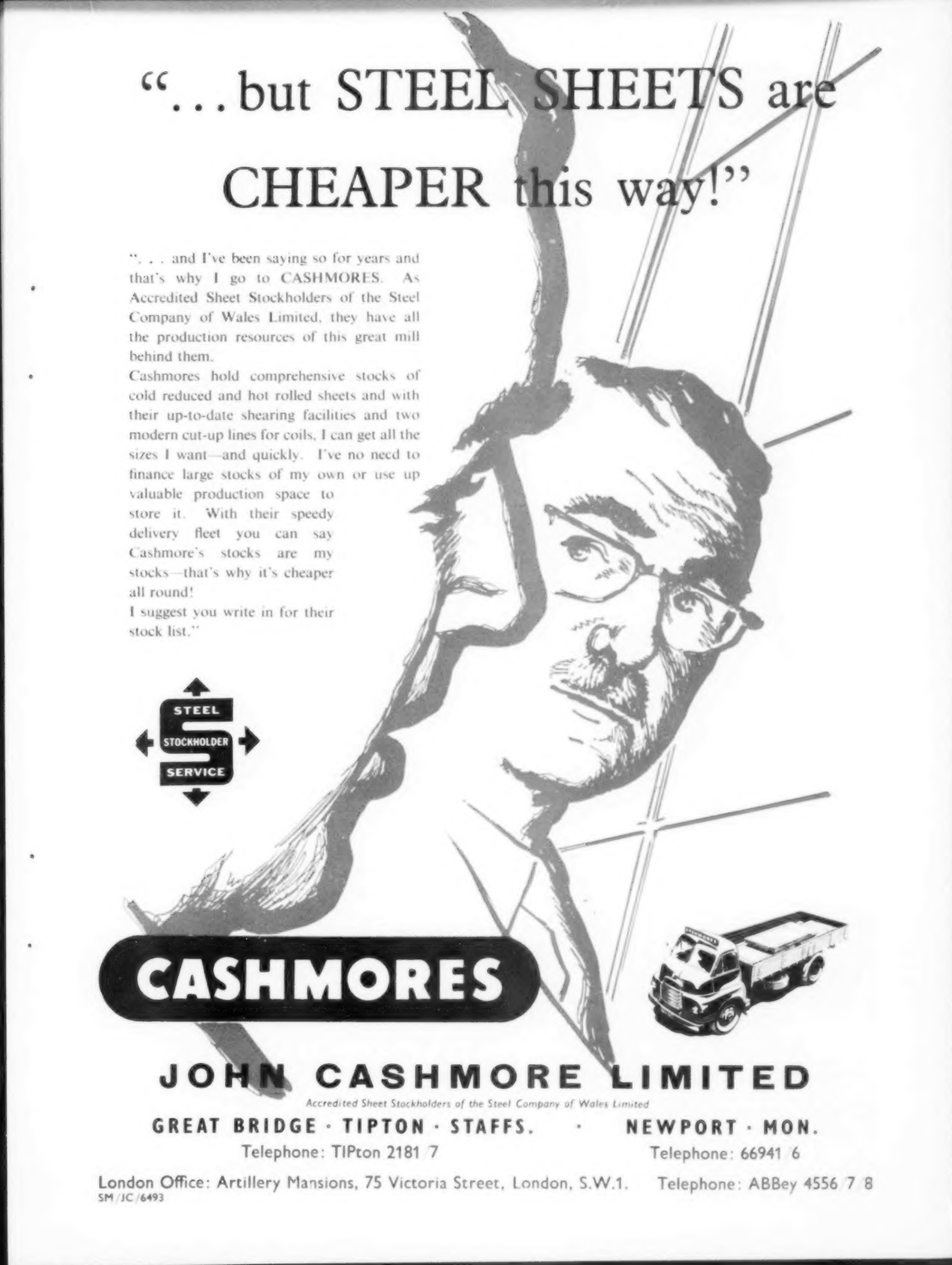
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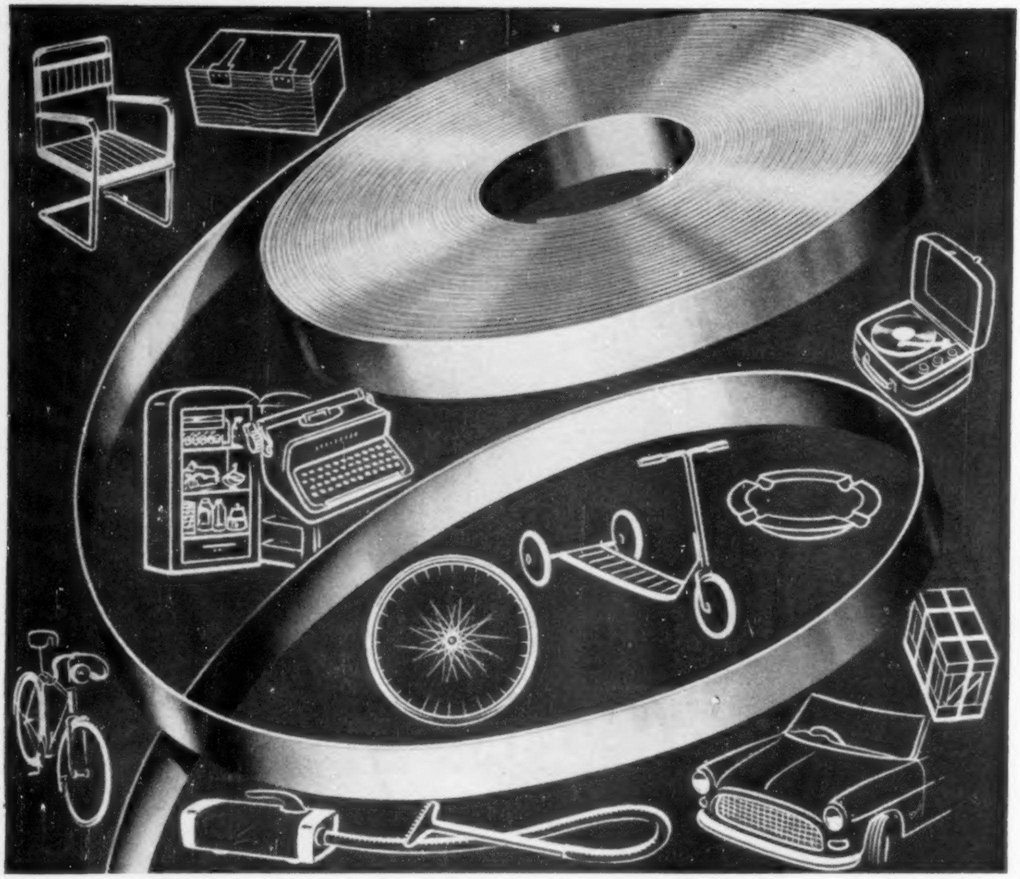

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in coils and straight lengths

All widths ¼" to under ½" X 0·008" to 0·064"
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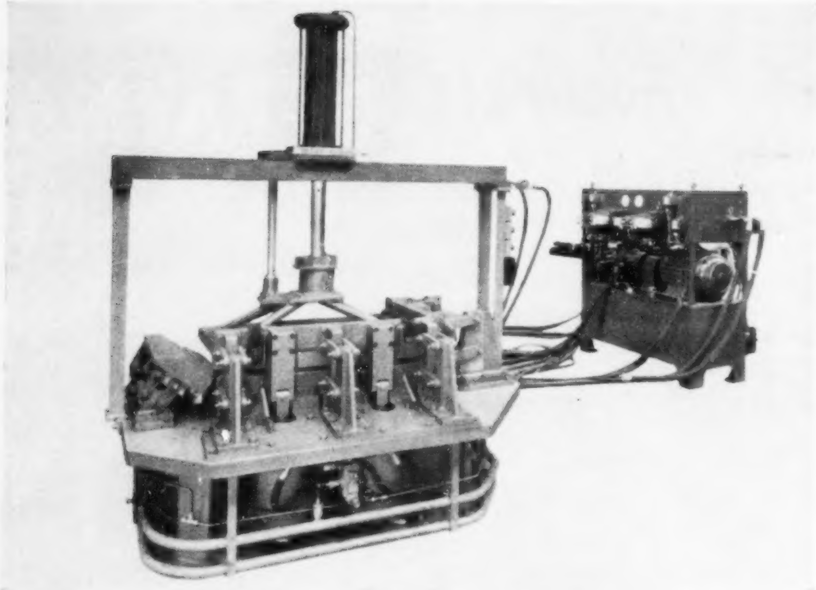

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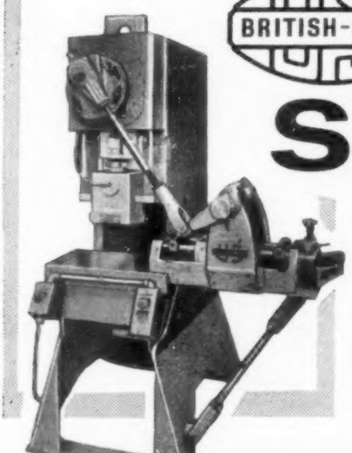
with the improved



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EASE OF ADJUSTMENT

No connecting rod adjustments required when changing feed lengths.

SYMMETRICAL DESIGN

Feed block operates from centre. Front and rear stops adjustable.

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Attached to feed body. Allows quick check of feed length. Eccentric is simply adjusted so that indicator points to desired length on scale.

MACHINED PAD ON SIDE BRACKET

for alignment with die.

SIMPLE ADJUSTMENT FOR STOCK THICKNESS

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SF-99A	9"	$9\frac{1}{4}$"	$\frac{1}{8}$"

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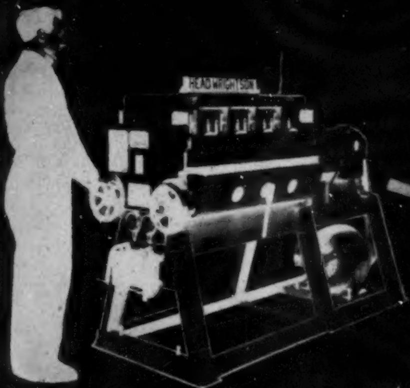
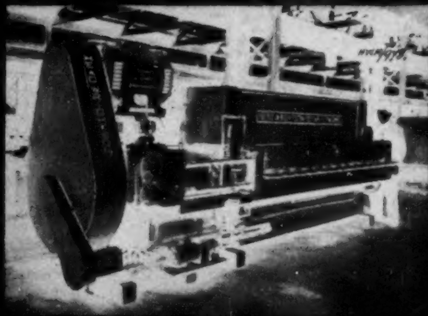
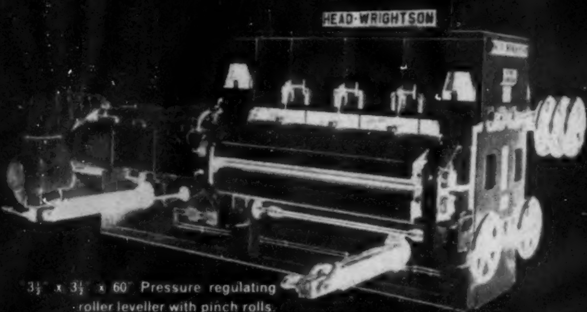


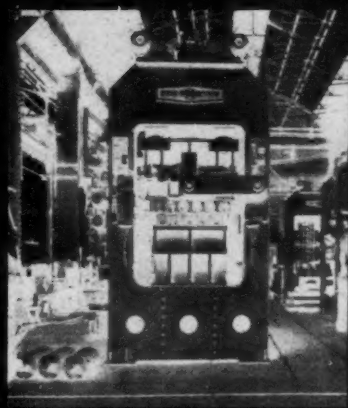
$1\frac{1}{8}'' \times 1\frac{1}{8}'' \times 36''$ Pressure regulating roller leveller, with four banks of back-up rolls for levelling aluminium foil.



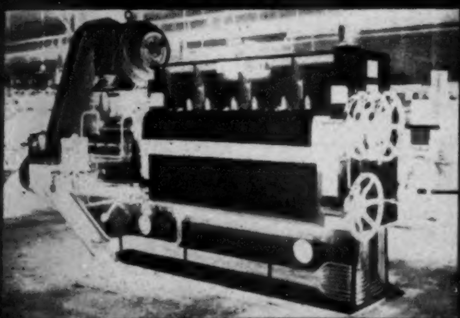
$2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 102''$ Processor leveller.



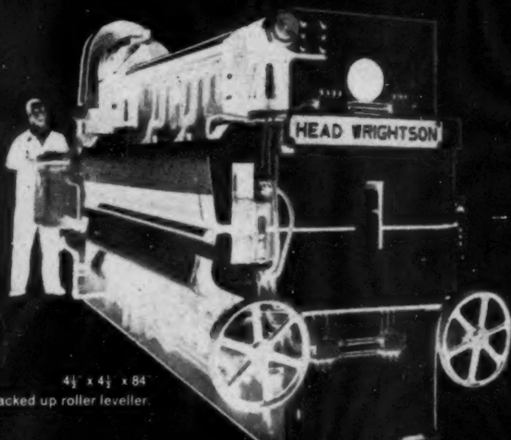
$3\frac{1}{2}'' \times 3\frac{1}{2}'' \times 60''$ Pressure regulating roller leveller with pinch rolls.



Three heavy plate levellers capable of levelling plate 12ft wide by 2 inches thick being built at the company's works.

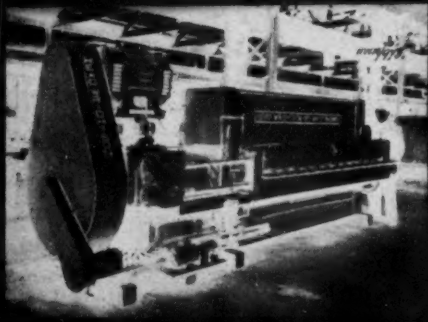


$1\frac{1}{4}'' \times 1\frac{1}{4}'' \times 54''$ Pressure regulating roller leveller.

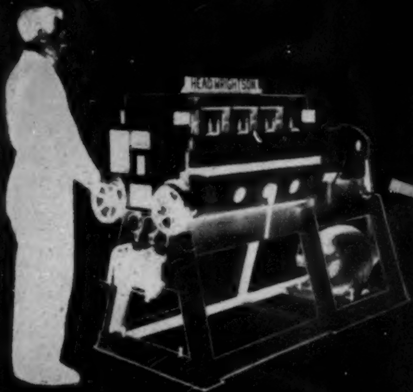


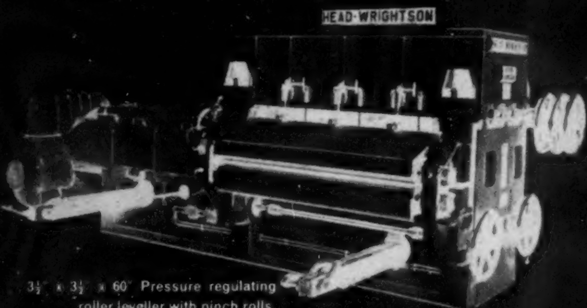
$4\frac{1}{2}'' \times 4\frac{1}{2}'' \times 84''$ backed up roller leveller.

$2\frac{1}{2}$" x $2\frac{1}{2}$" x 102"
Processor leveller.

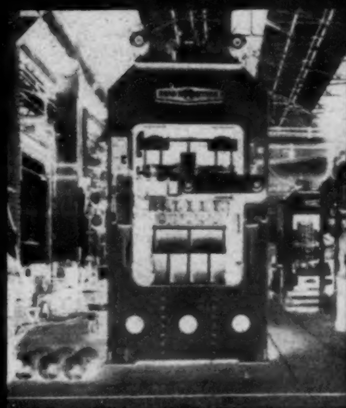


$1\frac{1}{8}$" x $1\frac{1}{8}$" x 36" Pressure regulating roller leveller, with four banks of back-up rolls for levelling aluminium foil.

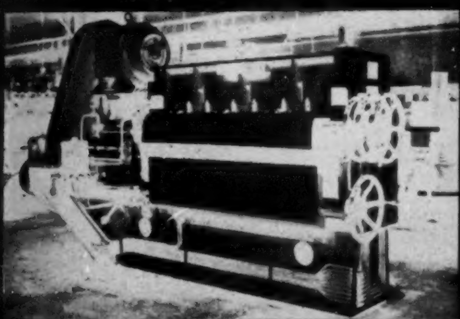




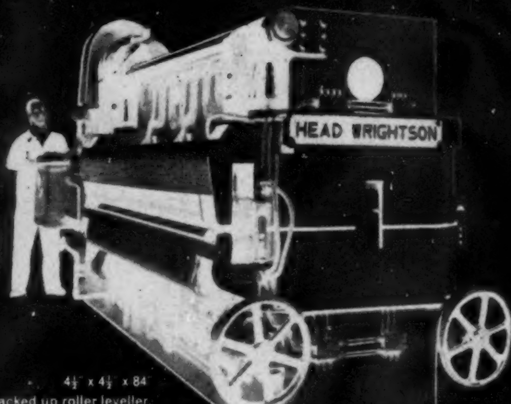
$3\frac{1}{2}$" x $3\frac{1}{2}$" x 60" Pressure regulating roller leveller with pinch rolls.



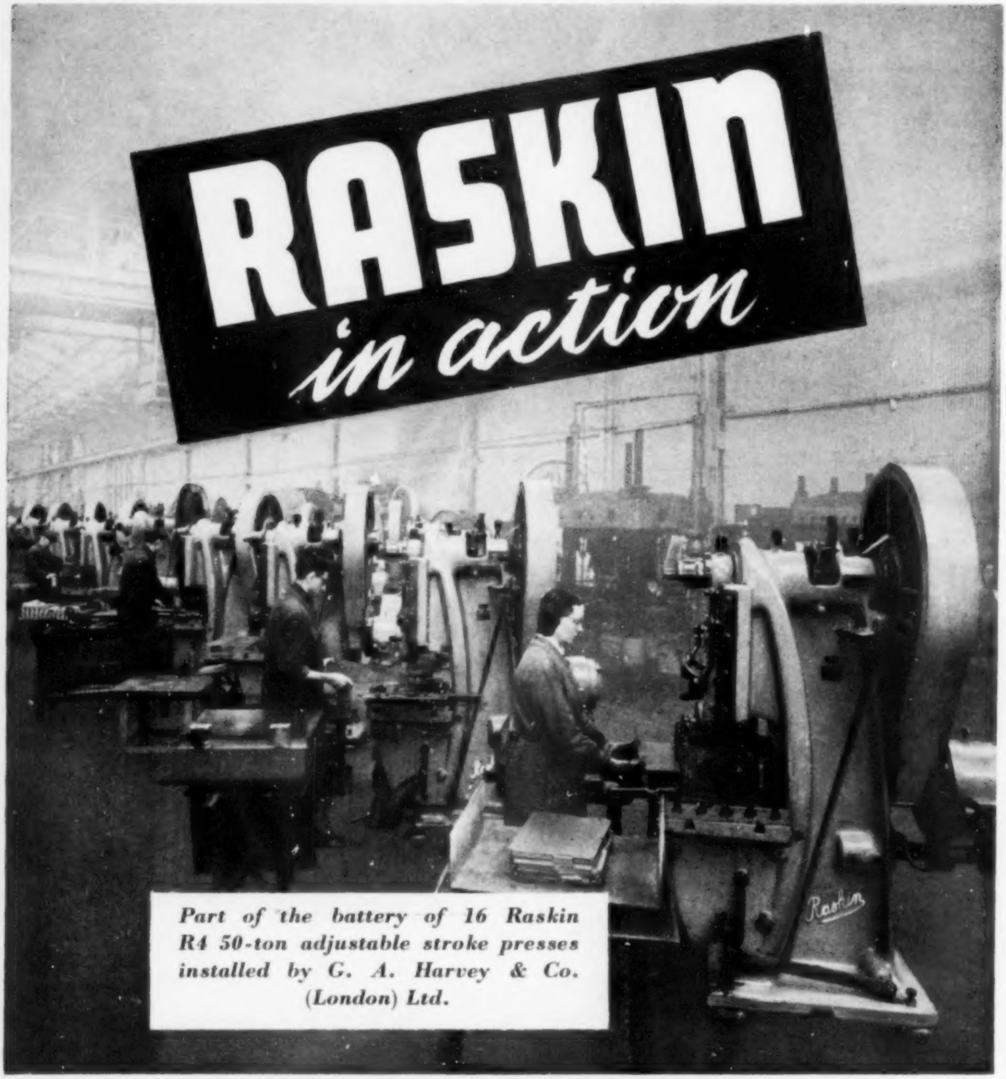
Three heavy plate levellers capable of levelling plate 12ft wide by 2 inches thick being built at the company's works.



$1\frac{1}{4}$" x $1\frac{1}{4}$" x 54" Pressure regulating roller leveller.



$4\frac{1}{2}$" x $4\frac{1}{2}$" x 84"
backed up roller leveller.



Part of the battery of 16 Raskin R4 50-ton adjustable stroke presses installed by G. A. Harvey & Co. (London) Ltd.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*The pressing assembly as produced by HOOVER Ltd for their **KEYMATIC** Washing Machine in their Merthyr Tydfil Press Shop illustrated on the opposite page.*

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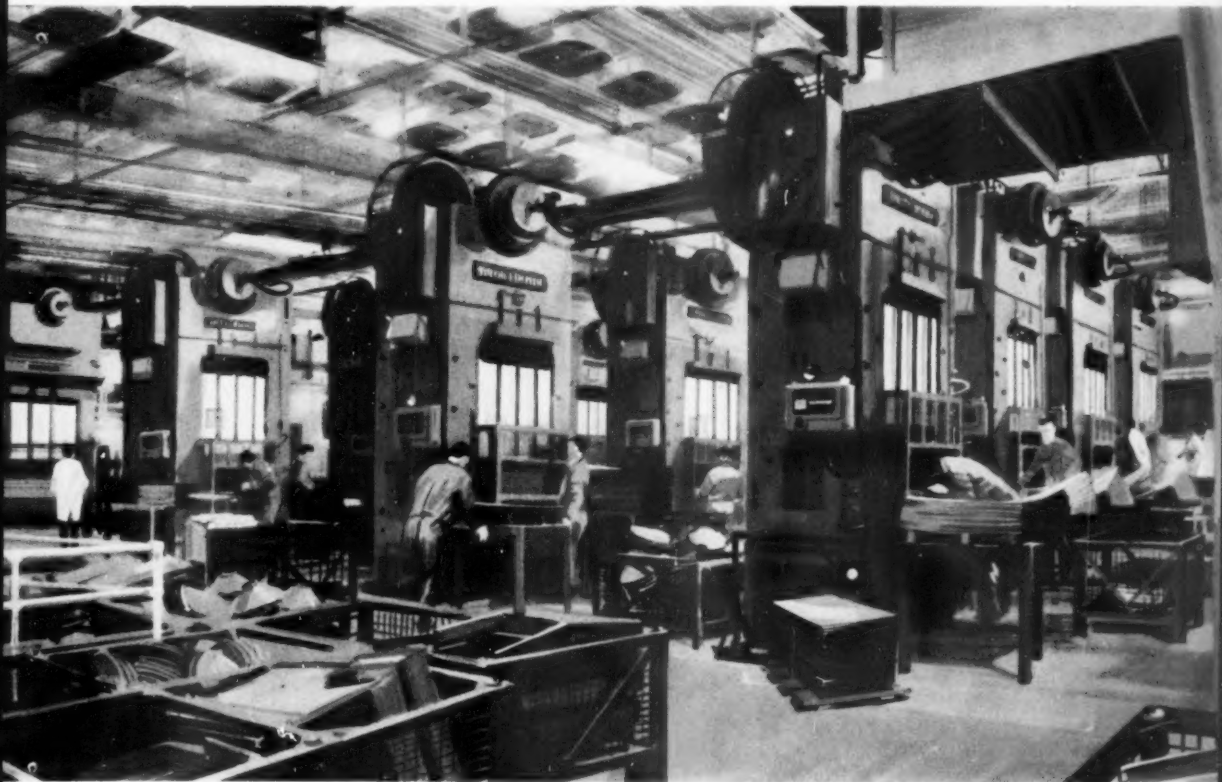

WILKINS & MITCHELL PRESSES (150 to 350 tons—36" to 108" between uprights) at work on HOOVERS latest washers.

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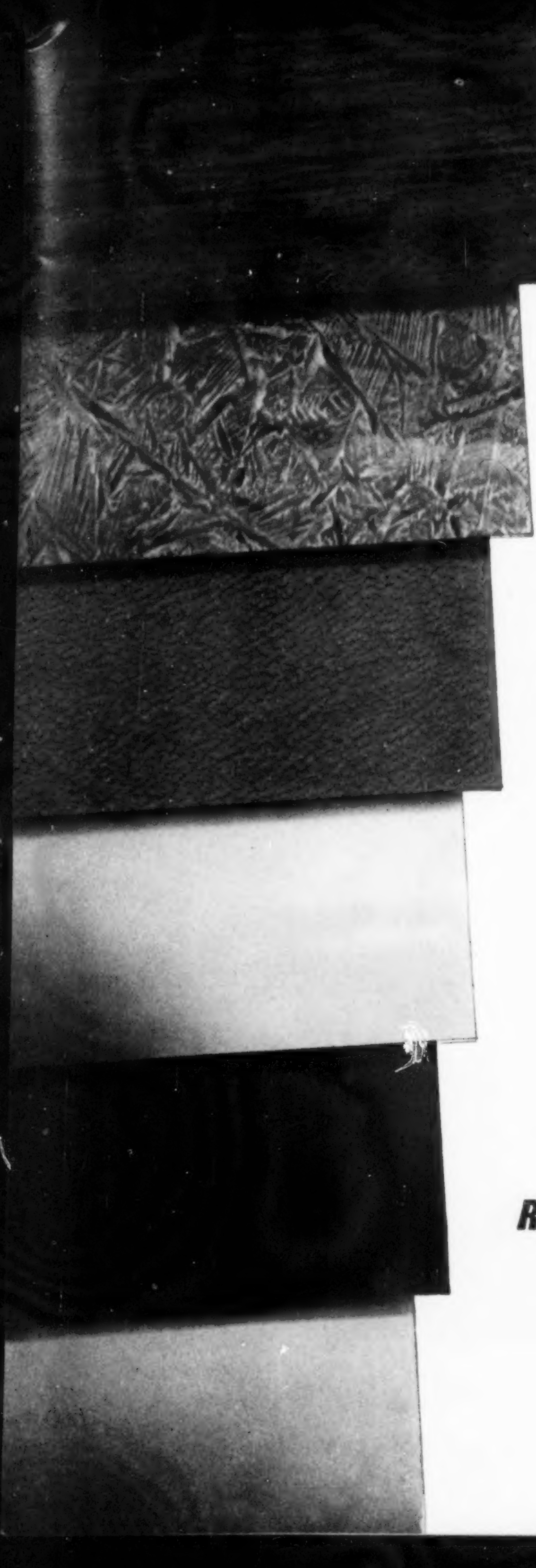

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OCTOBER 1961
No. 414 Vol. 38

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RÉSUMÉS DES PRINCIPAUX ARTICLES

Magasinage .. page 706

Cet article examine le rôle et le statut actuels des magasiniers de fer et d'acier en Grande-Bretagne, surtout en fonction de la disponibilité des larges feuillards d'acier sous forme de rouleaux. L'article comprend un commentairee émis pas un représentant de l'industrie de fabrication d'acier. De plus, l'article décrit deux magasiniers typiques se trouvant l'un dans le nord, l'autre dans le sud de l'Angleterre, qui peuvent offrir entre autres, du matériel pour la manutention, le guillotinage, le tranchement, l'aplanissement, etc. des larges rouleaux.

Anisotropie .. page 715

Par T. Ll. Richards, B.Sc., Ph.D., F.I.M., F.Inst.P.

Les métaux, du fait de leur résistance relativement élevée, de leur ductilité et de leur "formabilité", sont des matières presque idéales pour la fabrication de différents articles par emboutissage profond ou par l'estampage. Or, tous les métaux ont un défaut assez sérieux, soit l'anisotropie. Néanmoins, il semble que l'anisotropie, qui n'occasionnait jadis que des ennuis, peut à présent être utilisée avec avantage dans la production de bandes de bonne qualité pour l'emboutissage.

Evaluation quantitative de l'emboutissage profond et du façonnage à la presse par allongement. Qualités — 2 page 731

Par J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T.(Birm.)

Poursuivant l'examen de ce sujet, l'auteur traite d'abord d'essais d'emboutissage de cuvettes, tel que le test de Swift, fait un rapport sur les renseignements et les théories récentes au sujet de ces expériences, et considère également des procédés tels que les essais de cintrage, de lubrifiants, etc. Il examine également les méthodes de détermination du taux de pression.

L'inspection des tôles d'acier page 743

Par R. F. Lumb, B.Sc.(Hons.)

Les doublures des tôles d'acier peuvent se percevoir au moyen de méthodes qui font usage de variation de la

(*Suite page* 762)

ZUSAMMENFASSUNGEN DER HAUPTARTIKEL

Großhandel .. Seite 706

Der Artikel gibt einen Überblick über die derzeitige Rolle und Stellung der Eisen- und Stahlgroßhändler in Großbritannien, insbesondere in bezug auf die Lieferung von Breitbandstahl in gewickelter Form. Hierzu kommt ein Vertreter der Stahlindustrie zu Worte. Anschließend werden zwei typische Großhandelsfirmen aus dem nördlichen bezw. südlichen England beschrieben, die Einrichtungen zum Transport, Schneiden, Schlitzen, Richten usw. von gewickeltem Breitband besitzen.

Richtungsabhängigkeit Seite 715

Von T. L. Richards, B.Sc., Ph.D., F.I.M., F.Inst.P.

Wegen ihrer verhältnismässig hohen Festigkeit, Zieh- und Formbarkeit sind Metalle ein beinahe idealer Werkstoff für die Herstellung von Gegenständen aller Art durch Tiefziehen und Pressen. Alle Metalle haben jedoch einen recht schwerwiegenden Nachteil, die Richtungsabhängigkeit. Es scheint sich nun aber herauszustellen, daß sich gerade diese bisher so störende Eigenschaft sehr vorteilhaft zur Herstellung von Blechen mit guter Ziehfähigkeit ausnutzen läßt.

Quantitative Abschätzung von Tiefzieh- und Streckformeigenschaften — 2 Seite 731

Von J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T.(Birm.)

In Fortsetzung seiner Übersicht über diesen Gegenstand behandelt der Verfasser zunächst Prüfbecherversuche, z.B. die Swift-Probe, und bringt hierzu die neuesten Ergebnisse und Theorien. Weiter erörtert er Verfahren wie Biegeprüfung, Schmiermittelprüfung usw. und diskutiert die Methoden zur Bewertung der Beanspruchung beim Pressen.

Die Prüfung von Stahlblech Seite 743

Von R. F. Lumb, B.Sc.(Hons.)

Schichtungen von Stahlblechen lassen sich durch Prüfverfahren feststellen, die auf Änderungen des elektrischen Widerstandes, des magnetischen Flusses, der Fortpflanzung von Ultraschall-Verdichtungswellen durch das Blech und auf der Reflexion von

(*Forts. S.* 762)

RÉSUMENES DE LOS ARTICULOS PRINCIPALES

Almacenamiento página 706

Este articulo pasa revista al papel que desempeñan y la posición que ocupan los almacenistas de hierro y acero en la Gran Bretaña, especialmente en lo que se refiere a la disponibilidad de fleje ancho de acero en forma de bobinas. Comentan sobre esto un representante de la industria productora de acero. Contiene también el articulo una descripción de dos almacenistas tipicos, uno en el norte de Inglaterra y el otro en el sur, que, entre otras facilidades que ofrecen, están equipados para el manipuleo, cizallamiento, etc. de la bobina ancha.

Resistencia direccional página 715

Por T. Ll. Richards, B.Sc., Ph.D., F.I.M., F.Inst.P.

Los metales, gracias a su resistencia relativamente elevada, su ductilidad y su formabilidad, son casi ideales para la fabricación de diversos articulos por medio del estampado profundo y corriente. Sin embargo, todos los metales adolecen de un defecto bastante serio o sea la resistencia direccional. Pero parece ser que ahora la resistencia direccional, que una vez era solamente un inconveniente, puede emplearse con ventaja en la producción de tira metálica con buenas cualidades para el estampado profundo.

Apreciación cuantitativa de las cualidades para el estampado profundo y la formación por estiramiento — 2 página 731

Por J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T.(Birm.)

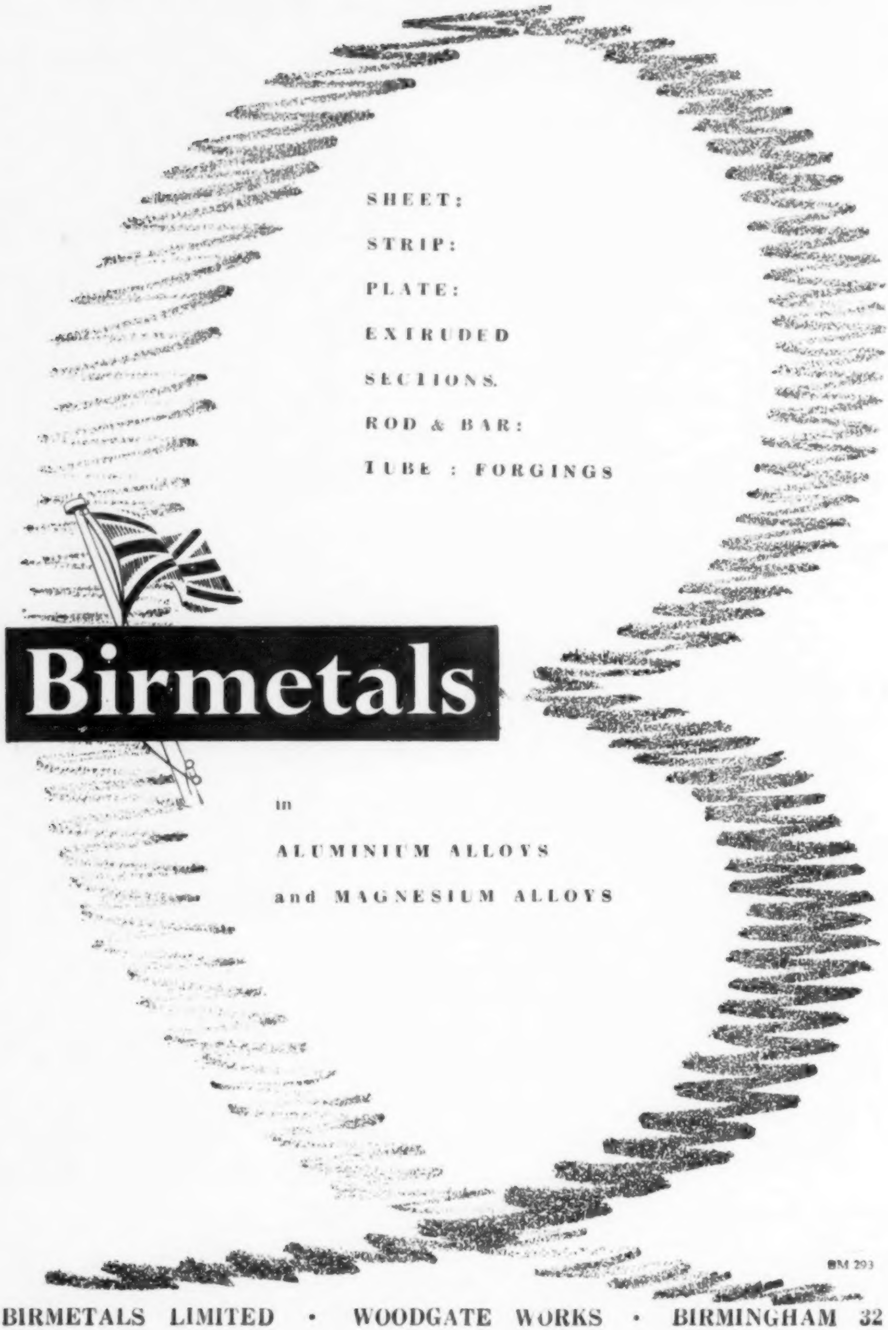
Prosiguiendo con su revista de este tema, el autor trata, en primer lugar, de las pruebas de formación de copas tales como el "Ensayo Swift" ofreciendo datos y teorias al dia sobre estas pruebas y estudiando también procedimientos tales como pruebas de doblado, ensayos de lubricantes, etc. También propone métodos para avaluar la severidad de los estampados.

La inspección de la chapa metálica .. página 743

Por R. F. Lumb, B.Sc.(Hons.)

Las laminaciones en la chapa metálica pueden descubrirse con métodos en los

(*Continuara en p.* 762)



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SERVICE IN THE BEST SENSE

IN the general order of things some produce, some sell and some buy, and it is this last category that should be the most important. The needs of the buyer must be the main objective of the producers, as without recognition of this prime factor the seller has a difficult task. Again, in the general order of things, some producers sell direct to customers, and some through a third party, the latter being the usual method.

In the iron and steel industry, however, the practice has been to use both methods; it is possible to purchase direct from the producer if the quantities are large enough, or through the iron and steel stockholders. Over the years the stockholder has become an increasingly important link in the industry's marketing chain and certainly his difficulties, in spite of the rapidly disappearing steel shortage, have increased rather than diminished, particularly as the range of products requiring to be sold increases. New types of steels, the introduction of pre-coated materials, and the need to take advantage of the availability of steel in the form of wide coil, are changing the pattern of stockholding, such that many stockholders have either installed or are planning to instal modern equipment for the handling and processing of this latter product. In the best sense this is good sense.

Because of the importance of this subject, elsewhere in this issue we publish comment on the present role and status of the stockholder, and in addition, brief descriptions are given of two typical stockholding organizations, one in the north of England and one in the south. As a further indication of the importance attached to the availability of wide coil the Institute of Sheet Metal Engineering, at its autumn conference in November, is devoting one of its technical sessions to the handling and processing, etc., of this product, and one of the five papers in the session will be presented by a steel stockholder.

Although there is always a tendency for a customer to resent the presence (and profits) of the "middle man", there could be few who would deny that he has a real part to play in speeding the general process of buying and selling and no really practicable alternative has ever been put forward.

It is, of course, possible to add to the cost of a product without adding to its value by inserting a number of additional and possibly superfluous agents between primary producers and customer, but this is not a charge that can be levelled at the steel stockholders who also provide "service" in many ways.

For example, stockholders in the past have acted as a valued buffering agent in reducing the impact of wild swings in supply and demand, one of the services they provide which has not always been fully appreciated by either customer or rolling mill, and there is no doubt that in the future they will be playing an even more important part in making it possible for the user of flat-rolled products to obtain exactly what he wants when he needs it. This indeed is service in the best sense!

STOCKHOLDING

A Comment on the Present Role and Status of the Iron and Steel Stockholder in Great Britain

The stockholder has always played an important part in the iron and steel industry in this country and the availability of steel in the form of wide coil has increased this importance. Below we give an impression of the stockholders' place in the industry from the point of view of a steel producer and also give brief descriptions of two typical modern stockholding organizations, one in the south and one in the north of England. The handling and processing etc. of wide coil will also be discussed at the forthcoming annual conference of the Institute of Sheet Metal Engineering.

WHY STOCKHOLDERS?

By L. C. SALTER*

MY company is conducting its own advertising in support of the National Association of Iron and Steel Stockholders' campaign aimed at making industry aware of the service the stockholders provide.

Such a step may well provoke the question—why should a large steel company encourage people who use steel to buy it from stockholders? That seems a reasonable question when, superficially, every sale through a stockholder appears to reduce the steelmaker's profit margin. Were the matter simply a question of profit margins, the stockholders' value to the steel industry, and its customers, could be a matter for debate, but there are considerations other than profit which make stockholders invaluable to all concerned with steel, whether as makers or purchasers.

But before going on to enlarge on those considerations I must emphasize that what I write is based entirely on my company's attitude as steel sheet manufacturers. I am not writing about steel stockholders generally. My observations are from the viewpoint of the sheet side of the steel industry only.

Why do steel-sheet companies have stockholders? The answer is because we consider them to be essential, indeed vital, links in a chain of distribution.

From a company's point of view one of the stockholder's great virtues is that he enables the company to spread its products geographically at strategic centres so that they are readily available to all consumers, especially the smaller ones.

Also, a stockholder's sales organization reinforces our own sales force in the field to an important degree. A stockholder's salesman selling from his company's stock is still selling our steel.

The stockholder is able to buy in bulk and sell small quantities where needed, often enabling the company to deliver in one lot steel that may ultimately go to many users.

Those are the main virtues of the stockholders from a company's point of view.

The stockholders themselves are well able to put their own case for the service they can render to industry but it is not out of place for me to mention one or two features of that service.

Speedy delivery is probably the outstanding. Orders needed urgently can be delivered promptly from a stockholder's reserves, whereas it would take a mill three to five weeks to produce them.

A stockholder's local knowledge often allows him to give a customer credit facilities when a steel company's knowledge is insufficient to do so.

Further, by dealing with a stockholder some steel-sheet users can reduce capital outlay, and also, by not carrying heavy stocks themselves, save taking up valuable space which can be used for production.

In addition, modern stockholders can supply customers with their requirements in exact sizes, thus obviating the need for the smaller steel users to have certain expensive equipment.

In recent weeks steel stockholding has been a topic of much conversation, and quite a lot of questions have been raised.

*John Summers and Sons Ltd.

Some I have heard are, I think, of general interest. I list them here with my answers:—

Q. Should stockholders be substantial in size, have adequate equipment, and their activities be confined to a specific area?

A. The steel-sheet stockholding business will develop, and indeed has already commenced to do so, on the same lines as in America where stockholders are substantial in size and equipped with modern machinery. The latter is obviously a "must".

It could well be that these larger stockholders, when developed, would find advantage in some co-operation with the smaller stockholder as a link in their chain of distribution, in order to cover the more distant parts of districts in what they may consider their area. I would think that because of cartage costs even the larger stockholder will confine his activities to an area, although this may be comparatively wide.

As the large stockholders would buy from the steel works in large quantities and, therefore, at more advantageous prices, the smaller stockholder may find it difficult to be competitive unless he could fit in the scheme of things with a larger organization.

Q. As a steel-sheet producer, do you think it is in the interests of the steel-sheet industry that some of John Summers' listed stockholders also handle non-ferrous metals?

A. To become a large stockholder in flat-rolled steel products, with modern equipment, means specializing and one would not expect, neither does one see in America, the efforts in the specialized business diverted by undue dealing in other products.

Q. Do you think that stockholders ought to have a qualified metallurgist on their staff?

A. Not necessarily, as they always have the sheet steel works staff to call upon to help them.

I do think, however, that much more could and should be done in giving stockholders' sales personnel a course of instruction at the steelworks. They should have this basic training, which can only be obtained at a sheet-steel plant.

Q. The suggestion has been made that the steel companies are going to raise the minimum quantities which can be bought direct from the mills, thus increasing the stockholders' business. Is this a good thing, and if so, why?

A. The modern method of production on a continuous strip mill is to use much larger slabs, producing coils up to 12 tons in weight. Obviously a maker is not anxious to supply in quantities of less than the yield from one slab or coil. Indeed, if production costs are to be kept to a minimum and, therefore, the costs to the consumer kept to a minimum, reasonable rolling quantities are essential. That is why there are price differentials between larger quantities of one size, gauge and quality, and smaller quantities.

Undoubtedly orders for quantities of less than the yield from one slab should be placed with a stockholder who can buy in large quantities, and the price schedule should be such that it would be advantageous for the user to do so.

A South of England Stockholder

A DESCRIPTION OF GRADES METALS LTD.

By J. A. COLES*

"DEAD STEEL" costs the user money—to be precise anything up to an additional 20 per cent on the maker's original price. But efficient stockholding—giving the customer steel when, where and as he wants—can save money.

Such is the principle motivating Grades Metals Ltd. in their approach to stockholding. The development of a close partnership between supplier and purchaser is essential if the appallingly high amount of money, estimated at over £180,000,000 lying idle in the stockyards of U.K. manufacturers is to be brought within sensible proportions.

But the stockholder must build up confidence by providing a full range to meet all possible requirements, no matter how frequently they change. He must establish an efficient service for prompt deliveries however short the notice. The author's company achieve this by ensuring that the men who answer the phone know steel and understand what the customers want and by installing guillotines, gang slitters, cut-up lines and flame profiling equipment to ensure that the customer is supplied with the steel in the form he wants it, and streamlining the warehouse so that stock can be moved quickly. This policy has proved successful in that in only 19 years, the company have become one of the leading stockholding and re-shearing concerns in the country. They were the first Southern stockholder to instal an automatic de-coiling, levelling, cut-up and slitting line for strip mill wide coil The company act as stockholders for John Summers and Sons Ltd. and were the first stockholders for Stelvetite plastic-coated steel sheet, and, as only recently announced, are also the exclusive Midland, Southern England and Wales stockholders for cold-rolled strip from the new Steel, Peech and Tozer Brinsworth Mill at Rotherham.

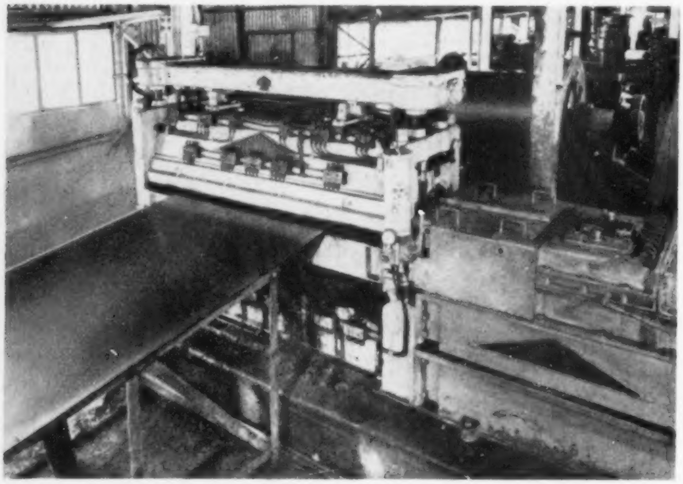
* Director of Grades Metals Ltd.

Currently the 4,000-ton stock at Chertsey includes strip-mill hot-rolled, cold-reduced, continuously-galvanized and electro-zinc-coated steel sheets and coils; cold-rolled steel strip in all tempers and finishes; strip-mill and plate-mill mild-steel plates and re-rolled mild-steel sections. Very large stocks are held of Stelvetite in a choice of ten standard colours which can be supplied at mill prices. To this list can also be added aluminium-alloy sheet, coiled strip, rounds, squares, hexagons, extrusions and special sections to A.I.D. and A.R.B. specifications. Coils can be supplied in the "as rolled" condition or prepared ready for the customer on the de-coiling, levelling and shearing line (Figs. 1 to 3) which can produce a maximum size of 15 × 6 ft.

In operation of this line a maximum-weight coil is passed on a carriage along the "railway line" shown in the foreground of Fig. 3, until such time as it reaches the coil holder. It is then passed forward between the adjustable cones and lifted by hydraulics until it lines up with the cones themselves. The cones are then electrically driven into the coil and the loose carriage is returned along the railway lines. The strip is passed into the Bigwood levelling rolls and adjustments made to ensure the correct degree of flatness is achieved. Comparison with the entry in Fig. 3 and exit in Fig. 1 will show the degree of flatness which can be obtained.

The strip is then driven along by the levelling rolls through the shear gap to a limit switch situated between the conveyors shown in Fig. 2. This limit switch is adjustable to produce any desired length. When the flattened sheet reaches the stop a hydraulic brake is applied while the cutting cycle takes place. On the return of the guillotine blade the limit switch momentarily disappears, allowing the cut sheet to be carried away by powered conveyors and at the same moment the hydraulic brake is released, permitting strip which has been looping behind the shear to come forward again for the next cycle.

There is also coil slitting capacity up to 48 in. wide by 5 tons in weight. The cutters are set up on two mandrels.



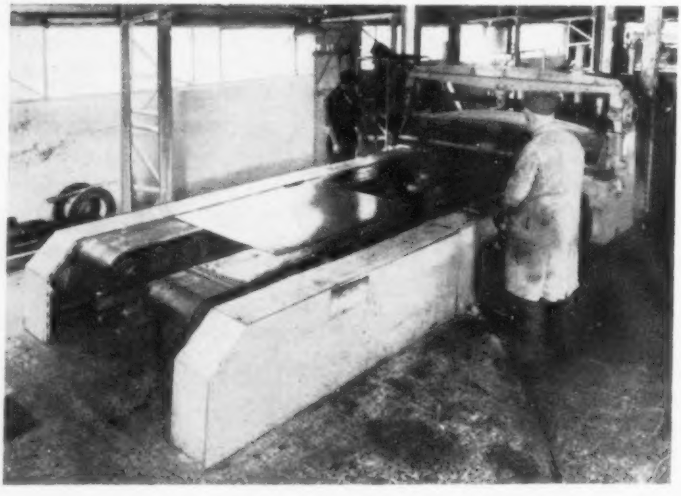
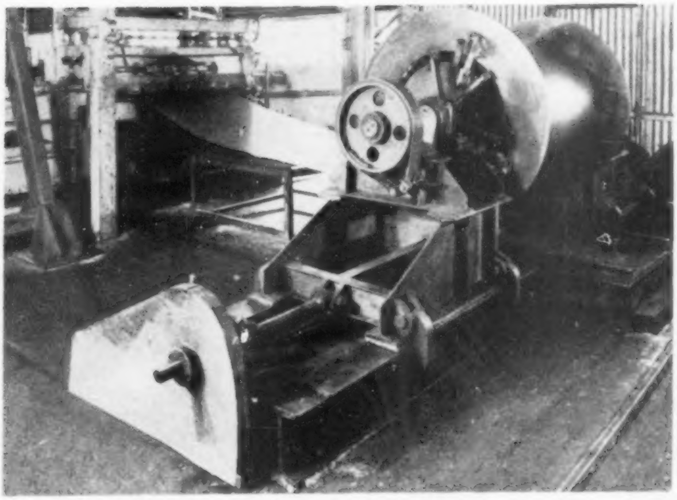


Fig. 1 (above).—Strip leaving 17-roll backed-up leveller of cut-up line at works of Grades Metals Ltd.

Fig. 2 (right).—Automatic cutting to length



The upper cutting disc is set so that it marries with the lower disc and this makes the initial cut. It follows that whatever size is required to be slit, can then be set across the machine with an up and down disc marrying and the result is that any variation can be supplied within an accuracy of plus and minus 0.005 in. Fingers are placed between the discs to ensure that the material is held in a flat condition. A slipping clutch ensures that the drive on the recoiler runs at a similar speed to the drive of the slitting discs.

A recently installed piece of equipment is the Cincinnati guillotine shear shown in

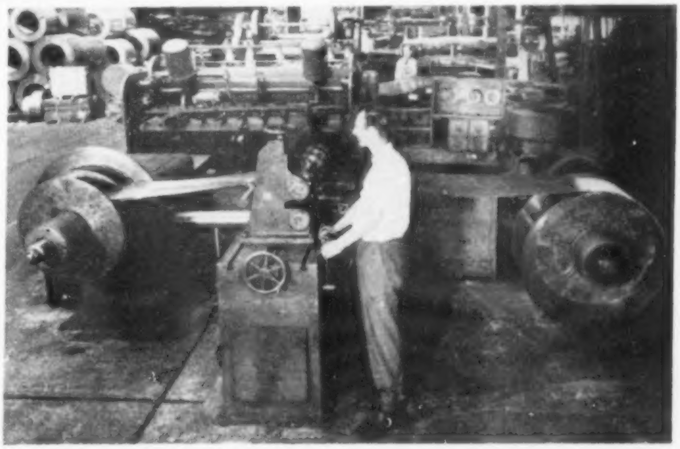
Fig. 3 (above).—Pay-off reel end of cut-up line at Grades Metals Ltd.

●

Fig. 4 (below).—Cincinnati guillotine shear

●

Fig. 5 (right).—Slitting machine for cold-rolled strip



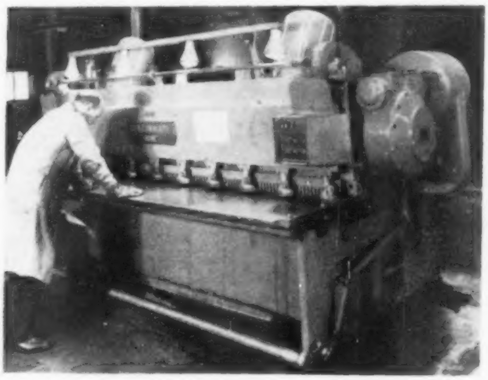


Fig. 4. The machine is capable of cutting 10 ft. $\times \frac{3}{16}$-in. plate at 60 strokes per minute. The box in the foreground of the picture operates an electrically-driven back stop and is adjustable to 0.001 in. Due to the rake of the blade on this type of machine, very narrow widths can be sheared comparatively free of twist. The back stop of the machine is fitted with permanent magnets so that wide sheets of steel are always retained on a level plane with the bed of the guillotine and this assists in obtaining extreme accuracy.

Emphasis on Exact Size

It is hardly surprising Grades lay such emphasis on providing the exact size and shape of metal required, since their origin was in the guillotine shop of A.B. Metal Products Ltd., the large

electronic component manufacturers. Wartime requests for cut-up capacity from other companies to A.B. Metal Products led to the establishment of a separate firm in a small workshop at Feltham in Middlesex, the name Grades being derived from initials of members of the Marks family who then owned A.B. Metal. Even though delivery lorries disgorged their loads onto the pavement (what horror for present day planning officers!) progress was rapid. Additional premises were soon acquired in Battersea and two years later all the company's activities were grouped together under one roof alongside A.B. Metal, the place where Grades started. Extensions to London airport in 1950 forced another move, this time to newly erected premises in Hounslow. Steady progress followed until even this accommodation became inadequate and plans were started to build the present modern warehouse in Chertsey which was occupied in 1959. The year 1960 saw further additions with the erection of a separate non-ferrous warehouse in Chertsey.

Activities commenced with a full range of aluminium—later enlarged to include brass, copper, bronze and stainless steel and already a large turnover has been built up in this new field in a comparatively short time.

The present 45,000 sq. ft. of warehouse plus a 6,000 sq. ft. modern office block is situated on a 2½-acre site. Additional equipment includes a 30-ton weighbridge and 10-ton overhead travelling cranes. The company's early policy of affording the utmost priority to questions of service to the customer continues.

A North of England Stockholder

A DESCRIPTION OF J. BARROW HOPE AND CO. LTD.

By JOHN MONK*

AN example of the modern approach to stockholding in the North of England, is the new works of J. Barrow Hope and Co. Ltd., Manchester, a company who have been established sheet steel stockholders for over 100 years.

Two new warehouses have been erected and equipped with 5-ton and 10-ton overhead electric travelling cranes, built by St. Michael Engineering Co. (Mcr.) Ltd., together with the latest handling equipment and weighing machines.

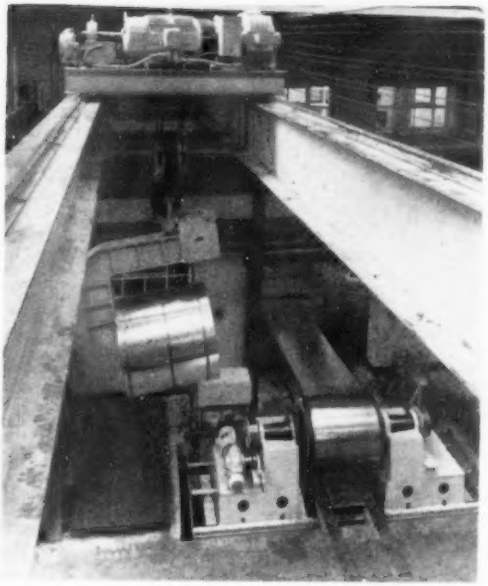
In addition, one of the most modern decoil, flatten and cut-to-length lines in Europe has been installed. This line is designed to deal with prime quality strip-mill hot-rolled, cold-reduced and galvanized coils, up to 48 in. wide and from 12 to 26 g. thick. Flattened sheets can be supplied to any length between 20 in. and 158 in., in length stages of 0.2 in. Cutting tolerances for short lengths is $\pm$0.02 in. and $\pm$0.08 in. for long lengths.

An oiling machine is incorporated at the end of the line, so that the material is available in the dry or oiled condition, according to customers' wishes. The quality of the sheets obtained from this line are comparable in every respect with those supplied by the strip mills in this country.

In order to serve its customers, not only a large stock of prime materials is maintained, but also it has a large quantity of John Summers' seconds and reject sheets, which are sold at very reasonable prices, and yet for many purposes are equally as good as prime quality steel sheets.

* Managing Director of J. Barrow Hope and Co. Ltd.

Fig. 6.—General down-shop view of Jersey Street, Manchester, warehouse of J. Barrow Hope and Co. Ltd. A further warehouse is in Murray Street



Quality	Thick-ness range	Widths	Lengths
Hot Rolled Drawing Quality, Flattened	12 B.G. to 16 B.G. (inc.)	36, 42 & 48 in.	20 to 158 in.
Cold Reduced Drawing Quality, Flattened, (Dry or Oiled)	14 B.G. to 26 B.G. (inc.)	30, 36, 42 & 48 in.	20 to 158 in.
Galvanized Working Up Quality, Flattened (from strip mill continous galvanized coils)	16 B.G. to 26 B.G. (inc.)	36, 42, & 48 in.	20 to 158 in.

The Bronx 10-ton decoiling machine possesses two cone heads which for lateral motion are operated hydraulically. The heads can be operated in or out independently, also a centralising movement is provided for which enables both cone heads to be moved in one direction or the other. Back tension brakes are fitted to both cone heads to prevent the coil over running. An electrical drive through spur gearing is fitted to one cone head for paying off purposes. In addition the de-coiler has a hydraulically-operated ram which lifts the coil to the required height to enable the cone heads to enter the bore of the coils.

In the combined Ungerer roller leveller and shear unit the roller leveller consists of 17 work rolls fully backed up. Tilt and swing motions are provided on the top bank of rolls. The bottom bank of rolls in addition to having a combined back adjustment, have individual back ups also which can be operated independently. This is a great advantage when only a certain section of the coil requires to be stretched to obtain flattened grade sheets. Combined with this machine to form one unit is a reciprocating shear. Unlike the usual shear operating mechanism for this type of equip-

(*Continued in page* 713)

Fig. 7 (above).—Coil hook loaded with galvanized coil on the 10-ton E.O.T. crane. The 10-ton Bronx decoiler is also shown

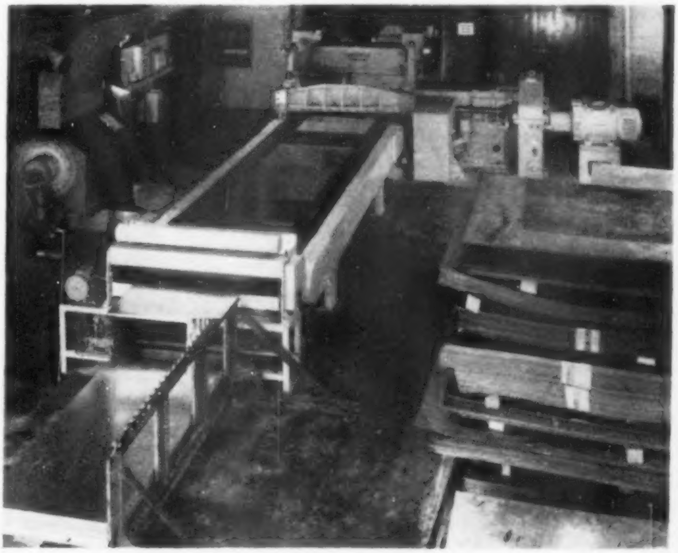


Fig. 8 (right).—View showing the exit side of the Ungerer shear followed by the continuous belt conveyor, the 2-roll oiling machine and lastly the stacking table. The ducting seen on the upper left side of this photograph is connected to an oil-fired heat exchanger supplied by A. E. Geaves and Son (Northern) Ltd., Chorley, Lancs. This unit supplies the offices and two warehouses with warm-air heating, this being particularly necessary since the company are sheet steel stockholders

Automatic Hole-Punching in Formed Sheet-Metal Sections

WHERE a multiplicity of holes have to be punched in sheet-metal parts, the complete advantages of the time-saving of multiple tooling are not gained if the small discs punched-out can in any way interfere with the process. This feature represented one of the weaknesses of earlier types of punching press layouts, where no provisions were made for instantly getting rid of these discs. With the advance of mass production systems, it was soon realized that anything which could jam the large press would be disastrous, and upset the timing schedule generally. Automatic indexing fixtures are installed in regular punching presses to control the punching operation, and each stroke of the press punches a number of holes in the metal. Where a bent, oval, or semi-circular section requires to have further holes punched, the fixture is then automatically indexed, and the operation repeated. Because of the presence of large numbers of small round discs, which might accumulate compressed-air is used to blow them out, after they have fallen into the hollow die where they collect. Often in practice, the punchings, instead of being ejected, tended to jam in the die-cavity. This was partly due to the exit-hole in the die of necessity being rather small. The cavity could be completely filled after a number of strokes of the press, when damage could be caused to punches, or die, or both. Less frequently the compressed-air supply failed, again causing a jamming of the punchings.

Arrangements for Protecting the Press

It was realized that some form of sensing unit, which would respond to the presence of the discs as they were being ejected, had to be devised. In order to make use of the magnetic characteristics of the discs, a coil and funnel arrangement was contrived, which is connected to the press in such a manner that after the punchings are ejected from the die, they pass into this funnel and through the coil (Fig. 1). While the coil is connected into a circuit which is normally balanced, and carries no voltage, in the presence of steel it becomes unbalanced. Hence a disc sets up a small voltage which is built-up by an ordinary two-tube amplifier, as it passes through the coil. As the punchings are blown from the die by compressed-air, they pass at comparatively high velocity through the sensing coil.

An ordinary relay cannot be made to operate satisfactorily on the amplified voltage, as the circuit is unbalanced for only a fraction of a second. For this reason an electronic relay is engaged that comprises a thyratron tube, which ionizes or fires even on a momentary pulse of voltage. It then

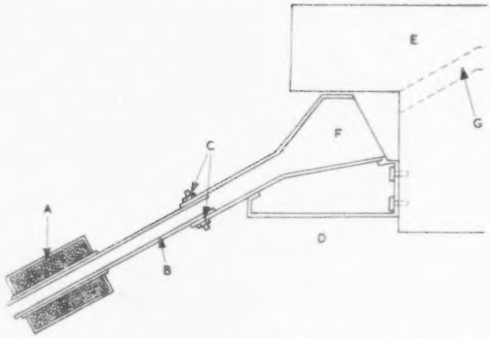


Fig. 1.—The punched-out discs, which are ejected by compressed-air from the die, pass through the coil prior to continuous discharge, while control by electronic timer forestalls any possibility of jamming, or failure to clear the die. "A" coil; "B" fibre tubing; "C" set-screws; "D" bracket; "E" die; "F" funnel; "G" exit tube

remains closed or conductive until its power circuit is disconnected by the punch, as the next cycle of operation commences. As long as the thyratron tube is conductive, the relay in the output circuit of this tube stays closed, and the relay-contacts allow the press to keep on running in this closed position. If the die is not cleared within three strokes after a jam occurs underneath the die, it is imperative in this application that the press be shut-down. An electronic timer, set for a time delay of some four seconds, which is the time necessary for three strokes of the press, accomplishes this safety shut-down. A resistor and capacitor in the grid circuit of a vacuum tube are responsible for controlling the time. With the sheet-metal part clamped in position over the die, the cycle of the punch-press begins with the punch at the top of its stroke. When the punch then starts its downward movement, a switch operates the solenoid valve, whereby the flow of compressed-air into the die is controlled. All steel discs left in the die from the previous cycle are blown out by the air blast, and as they pass through the sensing coil, they induce therein a voltage pulse. This fires the thyratron tube and energizes its relay, thereby preventing the electronic timer from starting its count of four seconds, or whatever count has been pre-determined. When the punch is on the upward or return stroke, the decks are cleared for another cycle, as it trips a switch that opens the thyratron tube.

Other Provisions Adopted

Should it happen that no punchings are ejected, the thyratron does not fire, and its relay does not close, so the timer commences. Where such conditions persist for three full strokes of the press, the timer will complete its cycle and operate a power

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Stockholding

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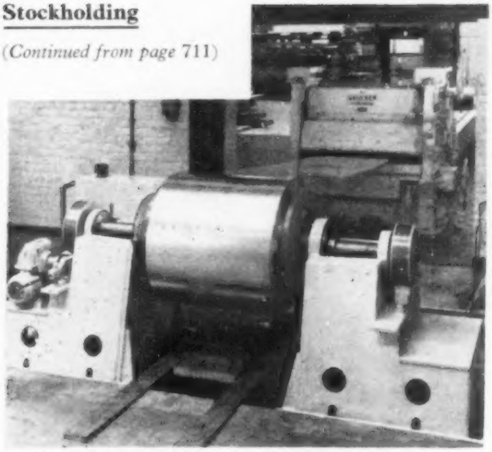


Fig. 9.—*A closer view of the* 10-*ton Bronx decoiler, also the entry side of the Ungerer roller leveller can be seen*

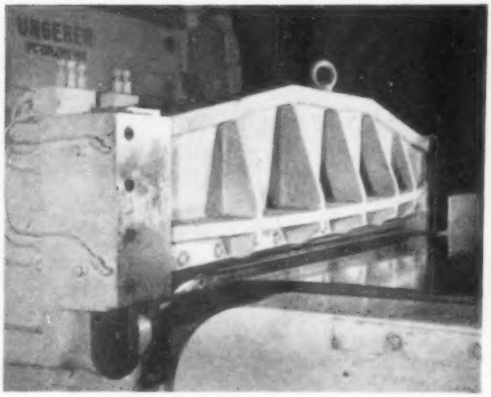


Fig. 10.—*A close-up view of the Ungerer shear which cuts the coil without interruption of flow*

ment (an adjustable length stop on the continuous belt conveyor) a small gear box driven by one of the work rolls is fitted and this in turn drives a further small gear box which is fitted with different gear wheels and contact discs to obtain different cut lengths. These can be interchanged quickly thus there is little delay in changing from one size to another. The latter gear box contains switch gear which in turn operates the coupling which drives the shear. Both the shear and roller leveller have a common drive through a main gear box by a 50-h.p. motor.

The continuous belt conveyor is of orthodox design and has the usual provision for tensioning and tracking the belt.

In the Bronx 2-roll oiling machine the rolls are lifted and lowered respectively when dry sheets are required.

The stacking table consists of a simple adjustable frame-work which provides support for the sheet one one side while it is manually supported and lowered on the opposite side.

Automatic Hole-Punching in Formed Sheet-Metal Sections

(*Continued from page* 712)

relay, whereby the press is stopped. In the vicinity of heavy machinery, and particularly a punch-press of any appreciable size, there is usually severe vibration.

With any piece of electronic equipment, the mechanical construction must receive prime consideration if it is to be successfully applied. Hence in order that vibrations will not adversely affect its performance or reliability, attachment of this equipment directly to the press has to be avoided. All electronic units are accordingly mounted in a separate cabinet, while they are so connected together by flexible cables and plugs that any one of them may be rapidly replaced should defective conditions develop. The provision of a switch is also made so that when it is closed, the press protector has no effect on the press operations. The need for this will be appreciated in order that the die setters can make adjustments without requiring to shut-down because there is no further ejection of discarded discs. In the past, a certain measure of success was attained by using elaborate light-beam systems for the same purpose.

These, however, often demanded careful mounting of sensitive tubes and optical components, right on the press, and which added materially to maintenance problems, and more frequent failures. While the electronic arrangement may appear complex it is really relatively simple, and comprises only two basic units, namely the amplifier, and the timer. The first actuates a relay as the discs slide through the coil which surrounds the ejection chute, and the timer which is re-started by the relay each time they come through, while the timer also shuts down the press should they fail to arrive within the pre-determined safety limit. There are numerous examples of bent or curved sheet metal sections which necessitate the foregoing protection and control during the punching of holes. In certain branches of automobile body construction, there are dash-board panels, steering column "envelopes", door connections, seat fittings, and a number of ancillary sections.

Semi-Automatic Welding of Television Components

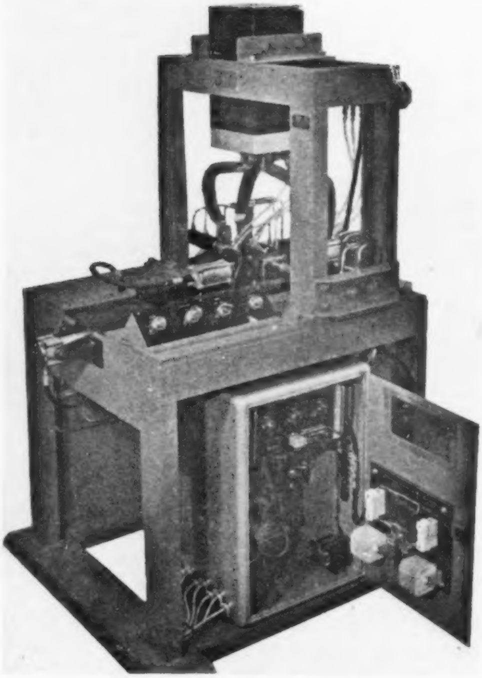


Fig. 1.—A general view of the television chassis-tuner unit welding machine, recently manufactured for Ferguson Radio Corporation by Electro Mechan-Heat Ltd., of Manor Works, Bilston, Staffordshire. The electronic control cubicle, whose door is open, clearly illustrates the ease of servicing. Beneath the transformer mounting can be seen the television tuner chassis in position. The air cylinder on the extreme left hand side is used to index the work table from the loading to the welding position. The other air cylinder attached to the work jig is one of the two clamping air cylinders

TWO special-purpose welding machines for the Ferguson Radio Corporation, who will use them at their Enfield works for high-speed production of the chassis and the turret-tuner spindle assemblies of television tuner units, have been built by Electro-Mechan Heat Ltd., Bilston, Staffs.

The machines, designed to produce one completed component every four seconds, are semi-automatic in operation. Welding cycles are controlled by electronic units embodying interlock devices, ignitron contactors and three-stage timers with printed circuits. Welding current is obtained from standard E.M.H. 45-kVA packaged welding transformers, connected to welding guns by flexible cables.

Fig. 1 shows the general appearance of the chassis welding machine. The control buttons can be seen on the top front of the loading table. Beneath, within the framework of the machine, is the control cubicle, containing the three-stage timer and the ignitron contactor. The open door emphasizes the ease with which the equipment can be serviced.

Chassis Welding Cycle

The chassis welder is provided with a pneumatically-operated work table, which is withdrawn from the welding position when at rest for easy loading. The pressing of two "start" buttons energizes a relay, which interlocks two push buttons to start the timer. The work table then moves forward to the welding position, where it trips a limit switch admitting air to the cylinders which operate the clamps.

Air pressure continues to build up in the clamp cylinders until it closes a pressure switch connected with an electrically-operated air valve. The opening of this valve admits air to cylinders which bring the four welding guns into position.

When the electrode tips make contact with the work, air pressure continues to build up in the gun cylinders until another pressure switch is closed to initiate the "weld" stage of the timer by firing the ignitrons in the primary circuit of the transformer and so causing the welding current to flow.

The weld stage is followed automatically by a "forge" period, whereafter the clamps are released, the welding guns retract and the work table returns to the load position. In doing so it operates mechanisms which re-set the welding control circuits and also a further pneumatic device whereby the welded component is partially lifted from the welding jig to facilitate its removal.

Turret-tuner Spindle Assembly

The welding of this component, which consists of two discs on a spindle, presented certain problems in the exact spacing and positioning of the discs.

A tolerance of only ± 0.0015 in. was acceptable in the location of one of these discs relative to a groove in the spindle. The spacing between the two discs had to be accurate to within ± 0.003 in.; and finally, certain holes in the two discs had to be

(*Continued in page* 722)

DIRECTIONALITY

in Sheet and Strip*

By T. Ll. RICHARDS, B.Sc., Ph.D., F.I.M., F.Inst.P.†

General Introduction

METALS, by virtue of their relatively high strength, ductility and formability, are almost ideal for the manufacture of various articles by deep drawing and pressing. Yet, all metals suffer from one rather serious defect, namely, directionality. Metal, single crystals, for example, have limited ductility in certain crystallographic directions and can be extended more easily in some directions than in others. When, in wrought metal, such as in rolled and annealed strip, a preferred orientation of crystals, or a definite texture is developed, then this can lead to pronounced directionality and to serious difficulties in the manufacture of pressings or deep-drawn products.

The main purpose of this survey is to indicate (i) why metals are directional, (ii) how preferred orientation is developed, (iii) what are the main consequences of preferred orientation and directionality, (iv) how directionality may be eliminated and, finally, (v) suggest how directionality may be used to improve the drawing quality of strip.

The Metallic State

The metallic elements are characterized by the fact that their atoms have, in general, only one, two, or three electrons in the outermost shell. In a metal crystal, these electrons are freely shared between all the atoms in the structure. It is possible, therefore, to adopt a simple model of a metal as a regular array of large positive ions in a cloud of electron " gas." This model accounts for the high electrical and thermal conductivity of metals as well as for the simple packing arrangements in metal crystals and for the relatively high ductility of metals.

Directionality in Elastic Properties

Cohesive forces in a metal are mainly due to the electrostatic interaction of electric charges, and a regular arrangement of the positive ions would, in general, be expected to lead to different elastic properties in different crystal directions. Metals of cubic structure such as copper, silver and gold or iron, for example, have a much lower Young's Modulus in the direction of the cubic axes than in the direction of cube diagonals. This can be explained by supposing the " free " electrons have a preference for sites located on an interpenetrating lattice. Aluminium which is face-centred cubic like copper is not nearly as anisotropic elastically, while tungsten and molybdenum which are both body-centred cubic like iron are respectively completely isotropic or anisotropic in the reverse sense of the anisotropy of aluminium. It can only be admitted that neither the precise electronic structure of the atom of these metals nor the distribution of the " free " electrons in the lattice is yet known.

Plasticity and Plastic Anisotropy

If, as is assumed, the outermost electrons of a metal atom are relatively free, then a metal would be expected to be quite ductile since it can be deformed by relative movement of the atoms, or large positive ions, without much disturbance of the cohesive forces since no real bond between positive ions exist.

It is now known, from direct observation of the deformation of metal single crystals, that deformation occurs by shear on certain crystal planes in atomically close-packed crystal directions. A metal crystal behaves, on deformation, rather like a pack of cards, but the shear or slip does not take place homogeneously on every parallel plane or over the whole extent of a single plane at any instant. The deformation occurs, in fact, by the movement of a structural discontinuity or dislocation. Such a dislocation is well illustrated by Bragg's bubble model. Since plasticity of a metal crystal involves the relative movement of atoms, then all metals in single crystal form or with a preferred orientation of poly-crystals are plastically anisotropic and metals such as aluminium and copper which have a similar face-centred cubic structure are equally anisotropic plastically, although *not* so elastically.

Close-Packing

Before leaving the atomic structure of metals, some reference must be made to close-packed structures. From the elementary model of a typical metal, we would expect metal crystals to have simple

* This article is based on a lecture included in a special course on " The Metallurgy of Deep Drawing and Pressing," held at the Department of Metallurgy, Birmingham College of Advanced Technology.

† Reader in Physical Metallurgy, College of Advanced Technology, Birmingham.

packing arrangements and this is indeed so, for most metals are either face-centred cubic, body-centred cubic, close-packed-hexagonal or tetragonal in structure.

Only the face-centred cubic and close-packed hexagonal structures will be considered in detail. Both structures, considered as a packing, of solid spheres, are equally close-packed, but they may be distinguished by the stacking arrangement of close-packed layers of atoms. In the close-packed hexagonal structure typical of zinc the layers are stacked so that alternate layers are directly over one another while in the face-centred cubic structure every third layer is repetitive.

As already indicated, the planes of close-packing are the slip or shear planes and it can be seen from the crystal models that there is only one family of close-packed planes in the hexagonal structure, while there are four exactly equivalent sets of such planes in the face-centred cubic metals.

Since plastic deformation generally occurs by short shear on the close-packed plane, zinc with only one set of shear planes has no ductility and is, in fact, quite brittle when extended in a direction perpendicular to these planes. With face-centred cubic copper crystals, on the other hand, no matter in what direction they are extended there is always a shear component on three of the four families of shear planes. This difference in availability of shear planes accounts for the fact that, in general, face-centred cubic metals like copper, silver, gold and aluminium are more ductile than metals of hexagonal structure like zinc and magnesium.

Anisotropy of Standard Polycrystalline Material

As is well known, wrought metal is an aggregate of small crystals usually in random orientation. If, however, there is a preferred orientation of the crystals then this will undoubtedly lead to directionality in plastic behaviour such as loss of ductility in certain directions of a sheet. A metallurgist concerned with the manufacture of strip has, therefore, to design his production schedule so as to produce strip with a fine and random grain-size. It should be mentioned, in passing here, that the roughening or so-called "orange-peel" effect obtained with pressings made from coarse-grained strip is a manifestation of the fact that individual crystals deform and shear on their own differently orientated systems.

Before discussing the development and control of directionality arising out of preferred orientation, other factors that can give rise to directionality in wrought products should be mentioned.

In certain aluminium alloys, for example, brittle non-metallic inclusions are broken up and drawn out into stringers in the principal direction of hot or cold working and these naturally lead to reduced

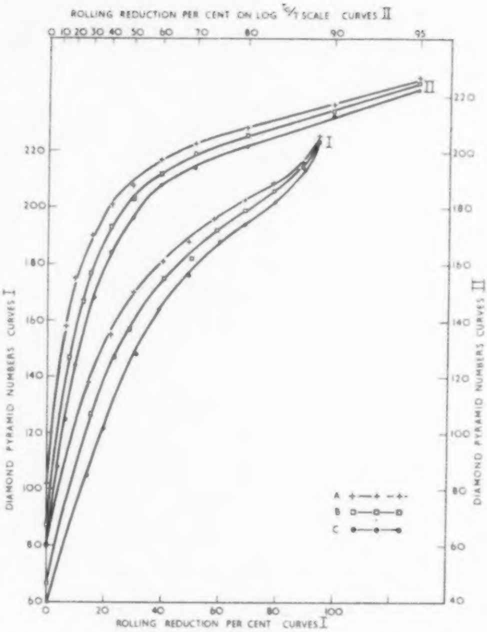


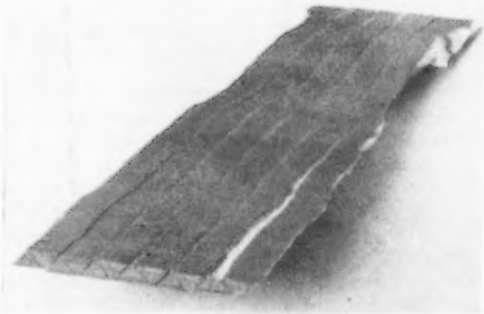
Fig. 1.—Work-hardening curves of cold-rolled 70/30 brass(1)

ductility in the transverse direction. The deleterious effect in sheet can be overcome to some extent by the appropriate amount of cross-rolling.

Effects Associated with Cold-working

Any particular metal or alloy in the annealed state appears to have limited ductility corresponding to the limit of uniform elongation in simple extension. If this is used up by prior working, then there is a corresponding loss of ductility in subsequent drawing operations. Hence, if it is necessary to stiffen aluminium alloy sheet prior to drawing then it is better to soften partially from a fully hardened state rather than to temper-roll annealed material.

If strip is rolled in excess of the degree of strain equivalent to the limit of ductility in simple extension, then it is found that deformation of individual crystals occurs by a form of brittle shear. This leads to directionality in the strip which is manifest as relatively low strength in the direction of rolling and poor bending capacity about this direction. During the rolling of 70/30 brass(1), for example, it has been observed that with reductions in thickness up to about 40 per cent plastic deformation appears to take place by shear on several slip systems so that each crystal is deformed more or less in proportion to the reduction of the strip itself. As Sir Geoffrey Taylor (2) explained,



this is a mathematical necessity if the strip is to remain in one piece and not break up at the grain boundaries. With reductions in thickness of 50 per cent or more there is evidence of a heavier and brittle type of shear on planes situated transverse to the rolling direction and inclined at about 35 deg. to the strip surface.

In work-hardening curves (Fig. 1), it can be seen that the initial deformation by slip is associated with rapid work-hardening and in the later stages, when the deformation is by the brittle shear, the rate of work hardening is much less. The deformation at the point of rapid change in rate of hardening is a good indication of inherent ductility of the initial

Fig. 2 (above).—Disintegration of over-rolled high-strength aluminium alloy[7]

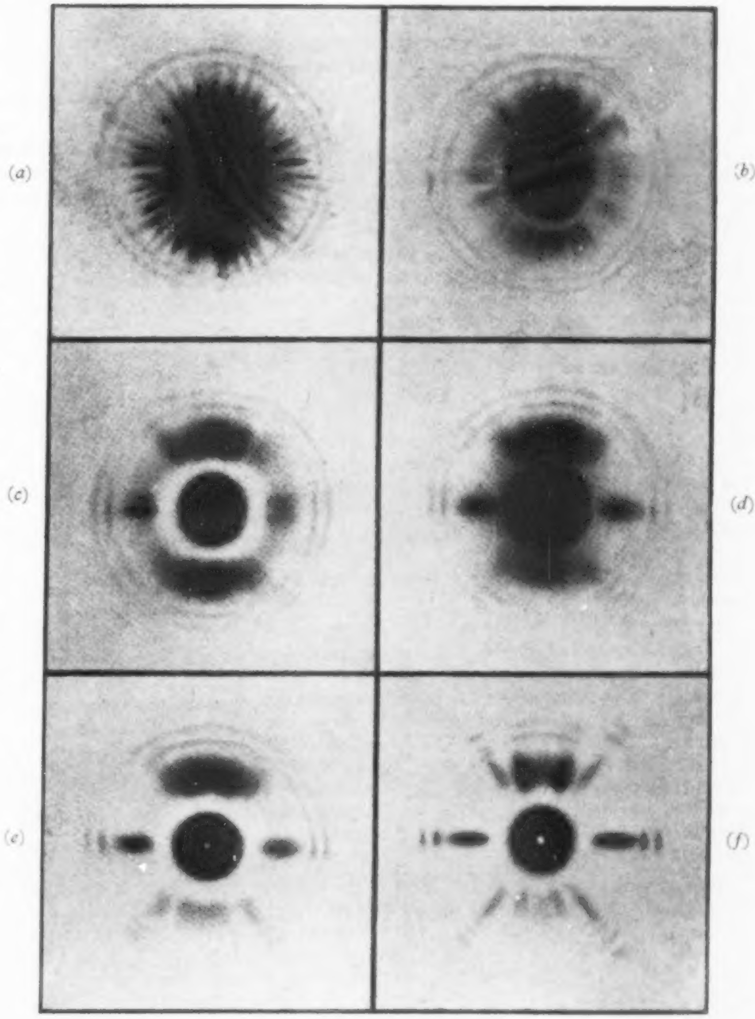


Fig. 3 (right).—X-ray transmission photographs of cold-rolled copper strip.[8] *Rolling direction vertical. Reductions* (a) *to* (f) *are respectively (per cent):* 10, 25, 50, 75, 85 and 97

(*Courtesy of the Institute of Metals*)

material for it represents the stage when the crystalline mode of of shear is exhausted.

Plastic deformation in one direction results in the strength in that direction being weaker than in transverse directions. This effect is usually only significant after very heavy reductions when the brittle type of shear has been operative and is more noticeable with alloys rather than with pure metals. With certain high-strength alloys the brittle type of shear can lead to complete disintegration of the material (Fig. 2), so obviously for the production of strip for deep drawing intermediate annealing must be introduced at appropriate stages.

Preferred Orientation—Textures

During plastic deformation, there is an obvious tendency for the slip direction, that is a direction of close-atomic packing, to align itself in the direction of maximum extension. Thus, during wire drawing, the slip direction turns towards the direction of extension and during compression the slip direction rotates away from the compression axis. Heavy deformation then results in a preferred orientation of crystals or well defined texture in the final product.

The effect of heavy deformation can be illustrated by reference to strip rolling. Rolling can be regarded as a combination of compression normal to the strip and extension in the rolling direction. Thus there is a tendency for the slip direction to lie in the direction of rolling.

With hexagonal metals, like magnesium, all the slip directions lie in a single plane, the basal plane of the hexagonal lattice. Magnesium can be hot rolled quite easily at a temperature about 220° C. but a high degree of preferred orientation is developed with the basal plane lying parallel to the strip surface. Because of this, the strip has much reduced cold ductility and can only be cold rolled with small reductions and intermediate anneals.

With face-centred cubic metals, on the other hand, the consequences of heavy deformation are not usually so disastrous, for with their many slip systems, two or more of the operative systems take up symmetrical orientations with respect to the strain axes. In theory, at least, the deformation can be continued indefinitely provided, as in rolling, the principal strain is compressional. The development of preferred orientation, or deformation texture, in copper by cold rolling is illustrated by the X-ray patterns of Fig. 3.

Similar rolling textures with respect to the atomic arrangement are developed in metals of other crystal systems which again brings out the similarity in nature of the atomic cohesion of various metals. Since after heavy reductions most of the ductility of the strip is lost, it is usual to recover ductility by appropriate annealing. Metal formers therefore are not directly interested in directionality in cold rolled strip arising from preferred orientation.

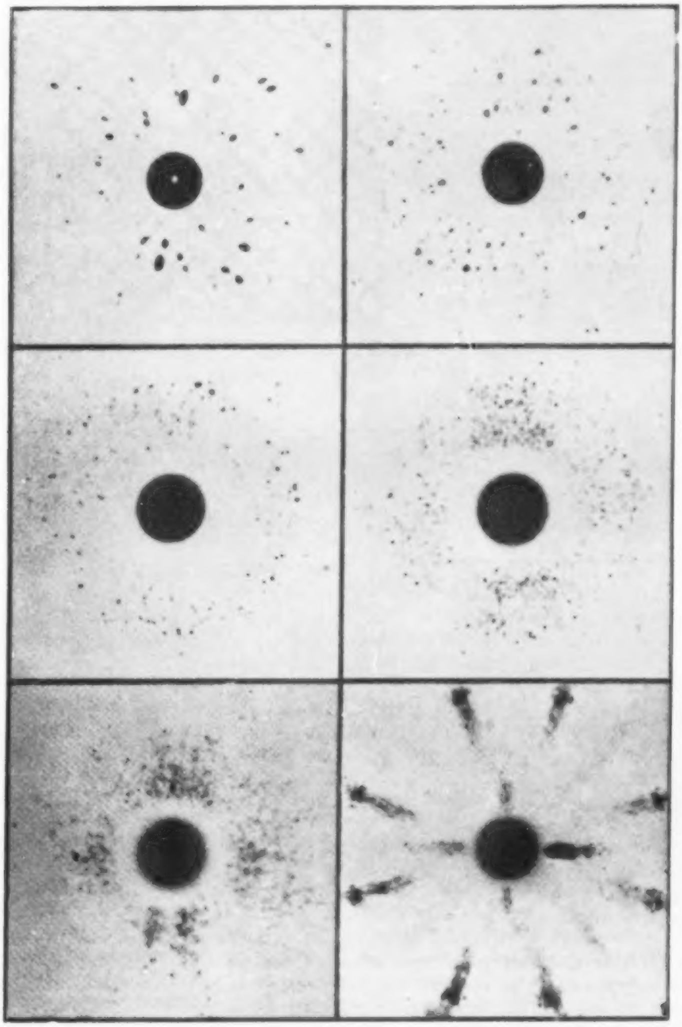
Preferred Orientation after Annealing

Before discussing the effects of annealing on the structure and properties of deformed metal, the structure of deformed metal must first be examined. Plastic deformation of polycrystalline metal requires the movement and generation of dislocations on several slip planes in any one crystal. While a few dislocations make it easy to initiate plastic deformation, as more are generated, these entangle and interlock, and the crystal structure becomes progressively more distorted and more difficult to deform. That is, it work-hardens.

On annealing, the first thing that happens is a movement and straightening out of dislocations to relieve lattice strains and elastic stress. In fact, a low-temperature treatment is often used, for example, with drawn brass products, for this very purpose. If the annealing is carried on for a long time at these low temperatures or for short times at higher temperatures, there is a general clearing up of the structure with cancellation of some dislocations and associated strain fields of opposite kinds and with the formation of a fairly regular and open network of interlocking dislocations. This results in the formation of fine strain-free crystallites or mosaic structure, the crystallites having orientations approximating to that of the parent grain. This process has variously been called, recovery, polygonization, recrystallization *in situ*, or primary recrystallization, depending mainly on the size of sub-structure.

At still longer times or higher annealing temperatures, new crystals are nucleated and grow in new orientations and this the author regards as recrystallization in the strict sense.

Deformed copper generally recrystallizes on annealing in the latter way, and recrystallization after reductions in thickness up to about 50 per cent leads to a random orientation of crystals (Fig. 4(*c*)) and to strip completely free from directionality. With reductions of the order of 90 per cent or more the crystals are deformed more or less in direct proportion to the reduction of the strip as a whole and take up one or other of symmetrical preferred orientations. On annealing recrystallization can now take place independently within the original deformed grains (Fig. 4(*e*)), or by interaction of the opposing strain fields to produce a completely new orientation (Fig. 4(*f*)), in which a cube plane of the cubic lattice is parallel to the strip surface and a cubic axis in the rolling direction. Such a preferred orientation is referred to as " cube texture " and, as may be expected, leads to highly directional strip. The amount of cube-texture in copper increases with decrease in initial grain-siz
e



(a) (b) (c) (d) (e) (f)

Fig. 4 (right).—As Fig. 3(*) with reductions (a) *to* (f) *(per cent) and grain-sizes (mm.) respectively:* (*a*) 10, 0.04; (*b*) 25, 0.035; (*c*) 50, 0.03; (*d*) 75, 0.025; (*e*) 85, 0.03; and (*f*) 97, 0.03

(Courtesy] of the Institute of Metals)

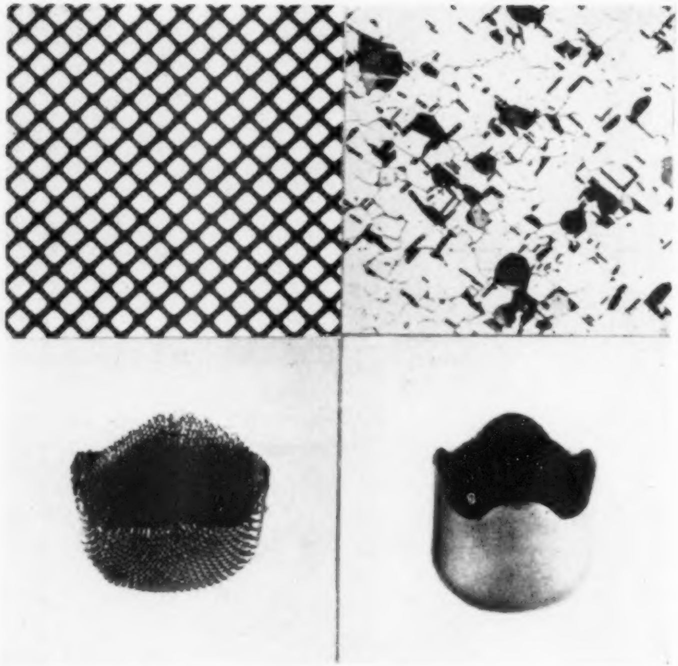
and with increase in final rolling reduction and annealing temperature.

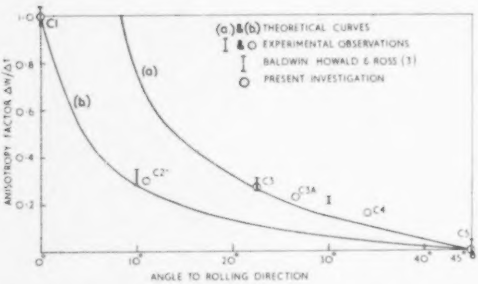
Aluminium, being also face-centred cubic, develops the same sort of textures as copper during cold rolling and annealing although is a little more subject to recrystallization *in situ*. Aluminium is accordingly a little more difficult than copper to produce with a random structure and, therefore, completely free from directionality, for one tends to retain and enhance textures developed at earlier stages in processing. Consequently, there is a tendency, with aluminium, to develop the preferred orientation and directionality corresponding to the rolling texture. Interaction of rolling textures on annealing to produce cube texture is, however, also possible with aluminium. Since the directionality associated with rolling texture counteracts that associated with cube texture the standard practice for production of directionality-free aluminium strip is essentially to effect a balance of the two textures.

Much is now known about the development and control of textures in other materials but, in general, their behaviour follows much the same pattern as that of either copper or aluminium. However, with materials, such as mild steel subject to a phase transformation, another method of control is possible. Iron transforms from a body-centred cubic structure below 910° C. to face-centred cubic

Fig. 5 (right).—"Earing" in forming cups from anisotropic copper strip and wire gauze ([9])

Fig. 6 (below).—Variation of the anisotropic factor in cube-texture copper strip([10])





above this temperature. It does this by a process of atomic rearrangement equivalent to shears on certain crystal planes, there being 24 alternative systems available. When heavily rolled iron, with a pronounced rolling texture is normalised, that is annealed above 910° C., the body-centred cubic texture transforms into 24 differently oriented face-centred cubic textures and, on cooling down, each of 24 face-centred cubic textures transform to 24 differently oriented body-centred structures so that in the final state the crystals are completely random in orientation and the strip directionality-free.

Directionality Arising out of Preferred Orientation

The effects of preferred orientation can be illustrated by the properties of copper-strip with crystals in cube-texture orientation. This has a low elongation of about 20 per cent in simple extension in cube directions, that is, in the rolling and transverse directions of the strip and an extremely high elongation, about 70 per cent in the intermediate 45 deg. directions, or cube-face-diagonals. This type of directionality becomes apparent in the old type of Erichsen test in which a spherical dome is pushed into a clamped sheet. The strains in the bulge developed are mainly radial extensions and four symmetrical fractures appear across the rolling and transverse directions of cube-texture strip.

Directionality is also very evident from the unevenness of the brims of cylindrical cups drawn from circular blanks. Copper strip with a completely random structure yields cups with perfectly level tops while cube-texture strip gives cups with very wavy tops with crests or ears at 0 deg. and 90 deg. to the rolling direction, *not* it should be noticed at 45 deg. which was the direction of maximum elongation in simple extension. This apparently anomalous behaviour is because the strain at the rim of a circular blank when forming a cylindrical cup of small diameter is mainly one of circumferential compression.

The formation of ears on cups from cube-texture strip can be readily understood by comparing such cups with those made from a wire mesh (Fig. 5). The wire mesh collapses in compression along one diagonal and pushes out as ears in the perpendicular direction. Similarly the close-

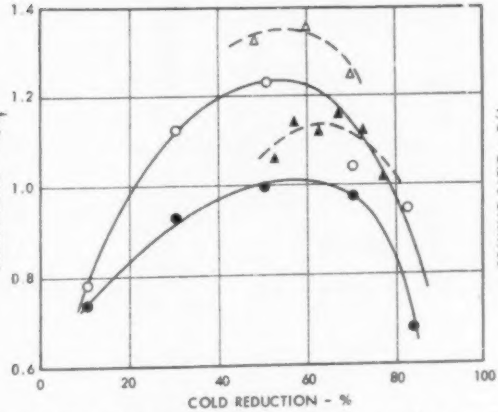


Fig. 7.—The effect of cold-reduction prior to annealing on the anisotropy of mild-steel sheet as measured by its average strain ratio([5])

Killed steels: △—*production samples* ○—*laboratory samples*
Rimmed steels: ▲— ,, ,, ●— ,, ,,

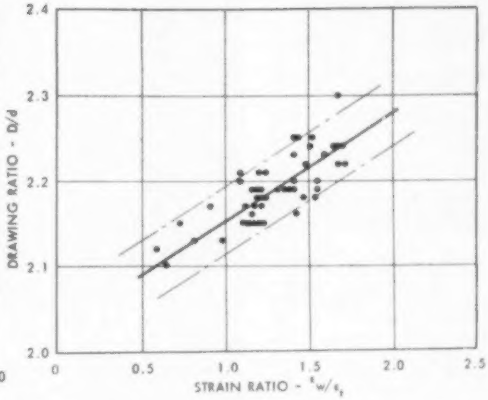


Fig. 8.—The relationship between the maximum cup-drawing ratio measured in the Swift cup-drawing test and the anisotropy of the metal as measured by its average strain ratio. The straight line relationship shown in the figure was established by a least squares analysis of the data. The dashed lines represent the 90 per cent confidence limits of this relationship ([5])

packed atomic rows, aligned parallel to the dark twins in the microstructure of cube-texture copper act rather like the rigid wires of the mesh and ears are formed in a corresponding way.

When aluminium is heavily rolled a texture is developed in which most of the close-packed atomic directions tend to lie in planes perpendicular to the strip surface and parallel or perpendicular to the rolling direction. If the strip is annealed at low temperatures the texture is unchanged and the ears developed on cups made from the strip are now at 45 deg. to the rolling direction.

The production of a cylindrical cup is often the first stage in the manufacture of articles from strip by deep drawing and the development of ears can not only lead to jamming of tools but may also necessitate an expensive trimming operation. The production of a cylindrical cup also provides a very simple and rapid means of detecting and assessing the degree of directionality in strip and this represents one of the features of the new Erichsen testing machine. However, the test is not altogether satisfactory for assessment of directionality and various attempts have been made to derive more useful information about anisotropy of strip from a simple tensile test.

The Anisotropy Factor

The first attempt to obtain useful information was by Baldwin, Howald and Ross([3]). They cut tensile test-pieces in various directions from cube-texture copper strip and measured the change in both width and thickness of the test-piece after different extensions during a tensile test. They then defined an "anisotropy factor" as the ratio of the proportional change in width/proportional change in thickness. They found that the value of this ratio was almost independent of the extension and dependent only on the direction of test-piece. Fig. 6 illustrates the kind of results obtained and includes the results of some confirmatory tests by the author.

Without going into great detail, the main point to notice is that the ratio has a value of unity in the rolling direction and practically zero at 45 deg. This is because during extension in the cube or rolling directions, four slip planes are operative and these are disposed similarly with respect to both the thickness and width directions while, for extension in the 45 deg. directions, slip is restricted to two planes making traces in the surface perpendicular to the direction of extension. No change in width is then possible and the anisotropy factor is zero.

By mathematical analysis, Bourne and Hill([4]) were able to show that earing should be expected in directions of the strip for which the anisotropy factor is a maximum. This is certainly true for cube-texture copper and it also applies to brass having a different texture. A more important conclusion that can be drawn, however, is that in the production of cylindrical cups, greater plasticity is obtained in directions of maximum anisotropy ratio.

It recently occurred to Whiteley, Wise and Blickwede([5]) that if it were possible to develop a texture which had a high strength normal to the strip and which was isotropic in the plane of the

(*Continued in page* 722)

Semi-Automatic Welding of Television Components

(*Continued from page* 714)

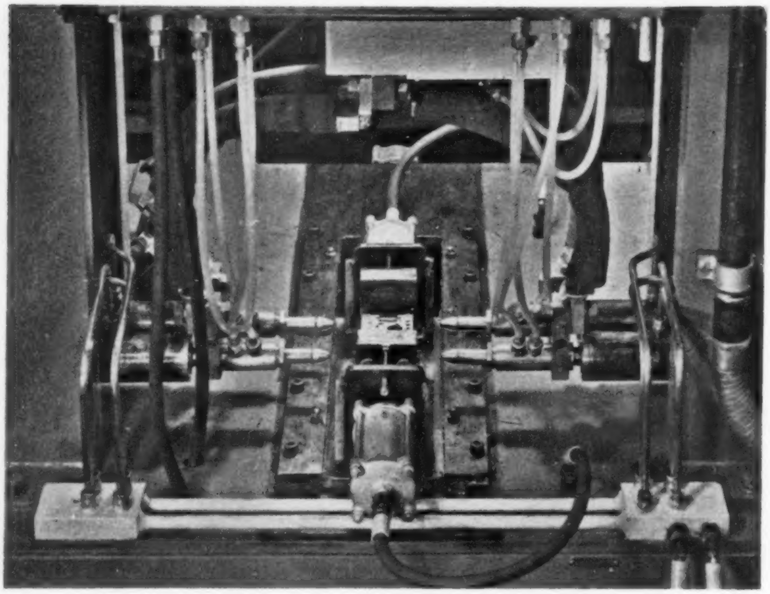


Fig. 2.—This photograph shows a close-up of the welding jig assembly. The welding electrodes and the component clamping air cylinders can be clearly identified in the centre of the picture

aligned to within an angular tolerance of ±0 deg. 15 min. of arc.

To ensure accurate location of the first disc, the spindle is held by a jig, which incorporates electro-magnets. The disc is then slid on to the spindle and the magnets energized so that the disc is drawn to an exact distance from the end of the spindle.

The second disc is held by another electro-magnet attached to the piston shaft of a small air cylinder. By this means it can be moved pneumatically to a predetermined position on the spindle relative to the first disc. Locating pins on the ends of both electro-magnets engage with depressions in the two discs to ensure their accurate angular positioning about the shaft.

The electro-magnets are operated by a foot switch, which allows the operator to engage the locating pins with the depressions in the discs before energizing the magnets. But once the "start" buttons have been pressed the magnets remain energized until completion of the full cycle of operations.

The first stage of this cycle is the moving of the second disc to its correct position along the spindle. Back pressure in the air cylinder which controls this movement is then used to actuate a pressure switch, whereby the welding gun solenoid is energized. Pneumatically-operated welding heads now move into position and back pressure in their air cylinders is used to close a second pressure switch and initiate the weld stage of the timer.

On completion of the welding cycle, the welding heads retract, the magnets are de-energized and the movable magnet returns to the load position. The welded component is then removed and fitted into a sizing jig, which consists of a forming block with two slightly conical faces against which the discs are pressed by impact cylinders until they conform exactly to the end faces of the block.

Directionality

(*Continued from page* 721)

strip then the anisotropy factor would be greater than unity and the drawing quality could be improved. The results of some experiments which these workers carried out on mild-steel strip to test their idea are shown in Figs. 7 and 8. These certainly prove that their hopes were well founded and it now appears that directionality which was once nothing but a nuisance can now be used to good effect in the production of good drawing-quality strip.

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The Selection and Forming of HIGH-STRENGTH MATERIALS IN AIRCRAFT*

Introduction

THE first decade since World War II has witnessed an amazing development in jet-powered aircraft. At the beginning of this period practically the entire airframe of most jets was fabricated of aluminium and magnesium. The uses of these materials have resulted in some fabrication problems, but they have never been considered real problems. Steel had very limited application because its structural efficiency was low compared with the less dense materials in the operating temperatures at the time.

A concentrated effort was made by a portion of the metals industry to produce a low-density high-strength material. The result was the production of commercially pure and δ manganese alloy titanium around 1949. Until this time, however, the principal emphasis had been on the structural efficiency of materials from a design consideration with little thought as to whether the materials could be fabricated. The initiation of titanium into the aircraft industry brought about a change in the relative importance of structural *versus* fabrication considerations. It was determined that in order to have a producible airplane, the manufacturing problems would have to be considered during preliminary design.

Ordinarily, the most promising features of a material from a design viewpoint are the principal limiting features from a manufacturing viewpoint. For instance, the two mechanical properties of strength and creep resistance are very important in design considerations. A high strength, however, is usually associated with a low ductility resulting in a low formability not only by elongation but also by buckling and distortion. These distortions are much more critical in manufacturing than is the limited elongation because they determine the amount of handworking necessary to produce a finished part. Springback in high-strength materials can be controlled in a production manner only by elevated-temperature creep forming, so that manufacturing, as opposed to engineering design, prefers low-creep-resistant materials.

The purpose of this report is to present the chief manufacturing limitations in forming these high-strength materials and to indicate the type of tooling that will be required. It is felt that, with a thorough understanding of the attractiveness of these new alloys and the problems associated with them for both engineering design and manufacturing, the most competitive airplane or missile can be designed and fabricated in production quantities.

DESIGN CONSIDERATIONS

The most important engineering design consideration in selecting materials for aircraft usage is structural efficiency. There are a number of methods of expressing this factor, but the more common one is the ratio $\frac{\sqrt{S_y E}}{\rho}$ where S_y is the yield strength in tension or compression, E is the modulus of elasticity, and ρ is the density. This is a very useful way to predict the relative efficiency of component parts because the ratio indicates both the strength and buckling for a given amount of weight for the materials considered.

The modulus of elasticity E is important because this is the principle parameter for considering buckling of thin sheet as shown by the general plate buckling equation,

$$S_{cr} = CE\left(\frac{t}{b}\right)^2$$

where S_{cr} is the critical buckling stress, b is the width of the plate, "t" is the thickness, E is the modulus of elasticity and "C" is a constant. Thus, buckling of thin sheet is seen to depend upon the modulus E and the thickness squared. A material with a high modulus will require a higher stress to buckle the sheet. For this reason, steel is better than titanium and aluminium in this respect. Also, higher gauges of material will also require higher stresses for buckling.

The density ρ of a material can be analyzed in two manners in the efficiency ratio. First, it

* A report from Chance-Vought Aircraft Inc., Texas, U.S.A.

determines the relative strength that can be attained for a minimum of weight. Second, the density controls buckling by controlling t for various materials. Lighter materials make it possible to use heavier gauges resulting in a more buckle-resistant sheet.

The yield strength is important in the efficiency ratio because it determines the amount of stress that can be applied to the part before permanent deformation is reached. Efficiency factors utilizing the compression yield determines the limiting stress level to which parts can be designed for buckling. High critical stress values can be used for high compression strength materials.

The dead-weight problem is another important factor to consider for aircraft materials. This term is usually associated with parts or a portion of a part that carries no load in the airplane. The more dense materials are less attractive for parts that do not carry loads throughout the structure. For this reason, the steels have to exhibit a considerably higher efficiency over the titanium- and aluminium-based materials for these parts before they are considered feasible.

The minimum bend radius is a third parameter which determines the usefulness of a material for design. The size of the bend radius will govern the efficiency of a part for three reasons: (1) It determines the width of the flange, thus controlling the weight. (2) It determines the placement of the load on the flange. (3) It controls the crippling strength of the bend itself. The larger the bend radius, the lower will be the crippling strength of the part. A number of materials such as 75S-T6, 4908 titanium, and 4340 steel (low heat treat) exhibit a maximum critical crippling value of the bend radius of around $5t$ to $6t$. Consequently, it is highly desirable that the bend radius be maintained below these figures.

Fatigue and creep are considered as secondary factors for evaluating materials. Fatigue can usually be controlled by careful design. Creep is more of a consideration on fighter aircraft than on missiles but the period of flight for fighters is still so small that creep is not a dominating factor.

The weldability of a material is important because it controls the cost and the efficiency of the airplane. The ability to spotweld an alloy is of particular importance because of the resulting reduction in weight by the elimination of fasteners such as rivets, nuts, and bolts.

Manufacturing Limitations

Elongation

Elongation had long been considered the chief limitation in the fabrication of metals; however, it is felt that this factor has been over-emphasized in its role in the forming of alloys in aircraft. It is true that elongation is the determining factor in predicting limits for parts that have fairly severe localized forming, but it is of secondary importance in forming most of the structural shapes in aircraft.

Elongation is the controlling factor in determining the formability limits such as minimum bend radius, dimpling, and deep drawing, and it is a fairly sizable factor in determining the limits such as beading, contour flanging, and recessing. All of these types of forming have been shown to correlate much better with the true strain, or zero gauge length elongation, than with the conventional strain, or uniform elongation. The ultimate failure is always restricted to a very small area in these types of forming because the instability that occurs in a tension test is not evident to a high degree. This is the result of considerable strain gradients across the fibres that are being stretched.

For instance, the minimum bend radius correlates very well with the ratio ϵ/S_{Ty} where ϵ is the true strain (reduction in area) and S_{Ty} is the tensile yield of the material[1]. The higher this ratio is for a material, the lower will be the minimum bend radius as shown by Fig. 1.

Actually the minimum bend radius is zero for materials whose ratio exceeds 0.058.

Beading, likewise, is closely associated with zero gauge length elongation because ultimate failure is always evident in a highly-localized area adjacent to the tangent of the bead as shown in Fig. 2.

Other less important material properties in beading is the tensile yield S_{Ty} and the conventional strain. Also shown in Fig. 2 is a typical formability limit graph. Curves of this type have been developed for the ordinary aircraft materials for the geometry of the beads as shown[3].

Contour flanging is partially limited by elongation, but it will be shown that this type of forming is limited principally by buckling (distortion). Very good correlation has been found with true

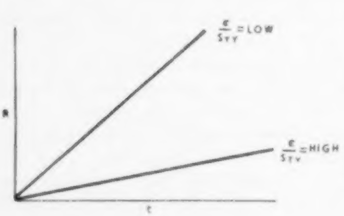
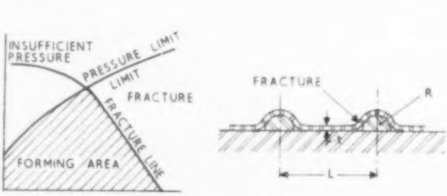
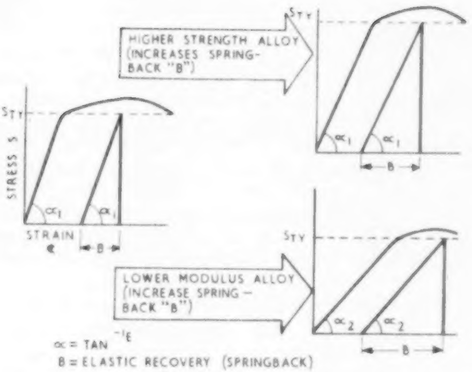


Fig. 1 (left).—Minimum bend radius graph for a high- and a low-ductility alloy

Fig. 2 (right).—Elongation limits for beaded panels by rubber forming





strain, for instance, in rubber-formed stretch flanges([2]). The relationship for this type of forming was found to be according to the ratio ε / A where ε is the zero gauge length elongation of a material and A is a factor depending upon the edge condition of the flange. "A" has been found to be equal to 1.7 for polished edges, 2.2 for deburred edges, 2.8 for machined edges, and 3.3 for sawed edges.

The formability of double-curved skins is dependent upon elongation only slightly. The longitudinal curvature of aircraft is so slight that, regardless of the transverse curvature, the total elongation required to shape outside skins is practically negligible. The elongation of most aircraft skins is of the order of 3 to 4 per cent; very seldom does the elongation of a skin exceed 10 per cent. The principal reason for failure of these parts in forming can be attributed to the operator striving to eliminate springback. This is particularly true in the stretching of high-strength materials.

Elongation, thus, has various roles in the production of aircraft parts. It is the chief limiting parameter for methods that produce severe local strains such as bending, dimpling, and deep drawing while it has about the same importance as buckling for a forming operation such as beading. Elongation is of secondary importance in predicting formability for such an operation as contour flanging while it is of negligible importance in predicting formability of double-curved aircraft skins. Where-ever elongation is considered, however, the better correlations can be made with the zero-gauge-length strain.

Springback and Buckling

As mentioned in the previous section, elongation has little influence on the formability of such parts as contoured structural members and double-curved skins. The formability of these parts is limited almost entirely by springback and buckling (distortion). As the bulk of aircraft parts are of this type, considerable emphasis will be placed on these types of parts.

Both springback and buckling can be very well represented for all materials by the ratio ε / S_{Ty} where ε is Young's modulus and S_{Ty} is the tensile yield stress([4]). Springback increases as ε decreases and S_{Ty} increases as shown in Fig. 3. Buckling of thin sheet, whether from direct applied stresses or resulting residual stresses, will also depend upon the ratio ε / S_{Ty} in the same manner as springback. As ε decreases, so will the necessary critical stress

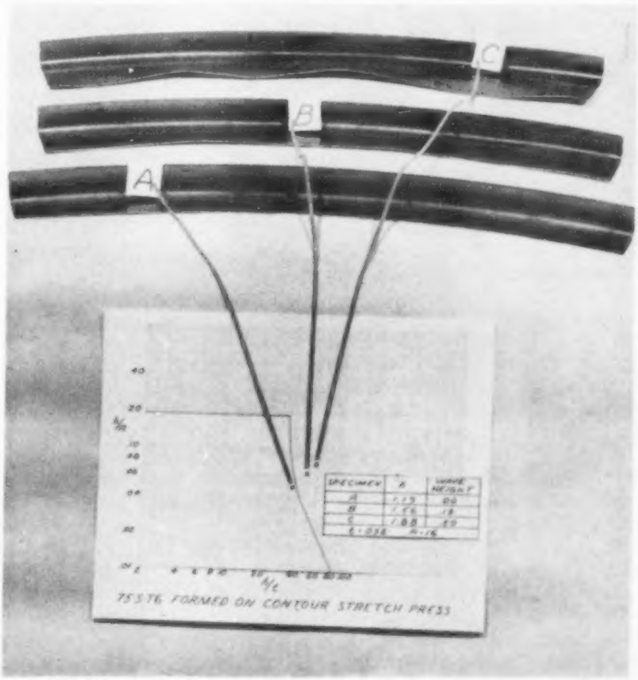


Fig. 3 (above).—Schematic stress-strain curve for typical medium-strength, medium-modulus alloy

Fig. 4 (right).—75S-T6 formed on contour stretch press

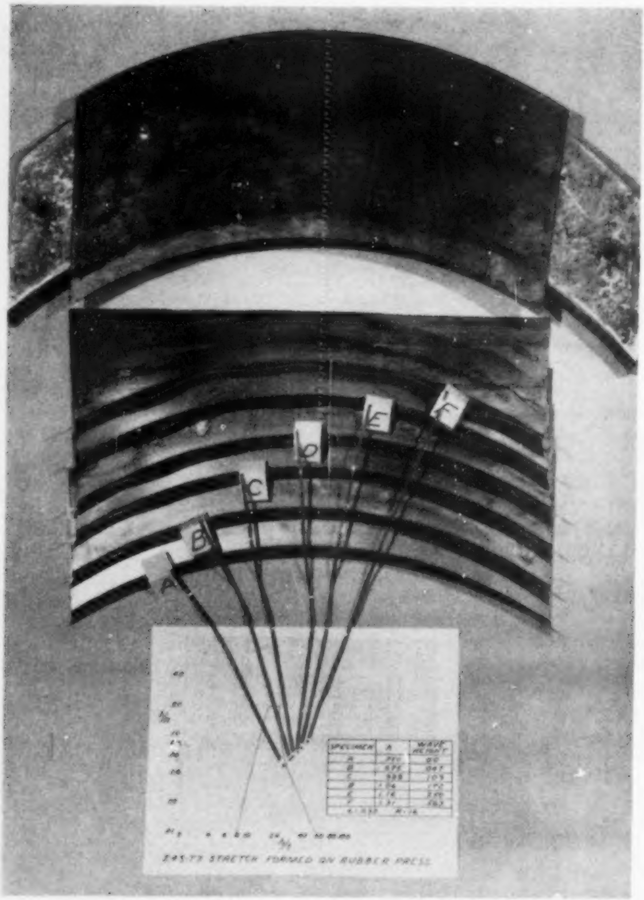


Fig. 5.—24S-T3 stretch-formed on a rubber press

to cause buckling. Also, as S_{Ty} increases, so will the necessary forming stress for a given strain. Consequently, as ε / S_{Ty} decreases, both springback and buckling will increase.

This springback and buckling will be evident on all types of parts; it is more prominent on free flanges and large unstiffened parts such as structural members and double-curved sheet. Beaded panels and recessed parts have integral stiffening so that springback and buckling is lessened.

Figs. 4, 5 and 6 show formability of simple structural members such as angle sections by the two basic methods of producing such parts at C.V.A., rubber press and stretch pressforming. Fig. 4 gives the formability envelope for 75S-T6 parts formed on the stretch press[4]. All parts whose geometry falls within the area bounded by the two lines can be formed without difficulty. The upper line represents the elongation limit of the material. A part whose geometry falls above this line will fail by fracture; however, this is usually above the normal practical geometry of parts in aircraft design. For instance, this type of failure is denoted on the picture as $h/R = 0.20$. Then, for a 1-inch flange, the contour radius is $R = h/0.20 = 1.00/0.20 = 5$. This means that a five-inch contour radius or less is necessary to fracture a 1-inch 75S-T6 flange. Most aircraft parts have a contour radius above 15 inches.

By far the most important portion of the curve is the buckling line shown as the curved, sloping line on the right. A part whose geometry falls to the right of the line will fail by buckling as indicated by the two angle sections shown. Part "A" is free from buckling while part "B" indicates incipient buckling and part "C" indicates total buckling.

Fig. 5 illustrates a similar curve for stretch flanges formed on the rubber press. This graph shows three lines forming the formability envelope and, again, the top line and the line on the right represent fracture and buckling respectively. The third line on the left is the machine limit or rubber pressure limit line. Stretch flanges on the rubber press are governed almost entirely by buckling just as are parts on the stretch press. In both cases, buckling occurs from residual stresses after the forming loads are released and not from direct applied stresses during forming.

Shrink flanges on the rubber press are governed entirely by buckling as shown in Fig. 6. The flange buckles into a sine wave during forming from direct applied stresses (unlike stretch press parts and rubber-formed stretch flanges) and is subsequently pressed into wrinkles with further

forming. Incipient wrinkles are evident on part "B", while the severity of wrinkles increase as the geometry of parts "C", "D", "E", and "F" fall farther outside the formability envelope.

Probably 95 per cent of contoured, structural, aircraft parts are limited in formability by buckling. The lower the index ε/S_{Ty} (high-strength materials) the lower will be the formability limits. Springback will also be increased as this index is lowered. Consequently, unless springback and buckling are controlled (as will be discussed in the following section), the high-strength materials will be very difficult to fabricate.

Double-curved skins can be formed by several methods: (1) sheet stretch press, (2) Anderson skin-forming machine, and (3) matched mechanical dies. The principal factor controlling formability on the stretch press is springback while the matched mechanical dies will be limited by buckling. The Anderson method has practically no limitations within the geometry of the machine. These methods will be discussed in the next section.

Because of the small forming strains and the large radii of curvature of double-curved skins, springback will be excessively high for forming high-strength materials on the stretch press. Compensations such as die development and hand working is not feasible so that one of the other two methods will be the only manner in which the parts can be produced.

The fabrication of beaded panels is controlled about equally by elongation and buckling, as mentioned previously. The buckling of the beaded panel will depend primarily upon the material (ε/S_{Ty}) and the edge conditions of the panel. Panels having flanged edges will increase the residual stresses considerably, resulting in a twist buckling of the part. This is usually negligible for the low-strength materials, but the condition cannot be controlled by ordinary means such as handworking for the high-strength materials.

Methods of Controlling Springback and Buckling

Springback and buckling have played a major role in controlling the producibility of airframes since aircraft have been made of metal. Several methods have been utilized for controlling springback, but, until recently no method has been devised for controlling buckling of parts during forming.

The first efforts at controlling springback were directed toward die development. This method was originated on the basis of making the die to a configuration other than the shape of the desired

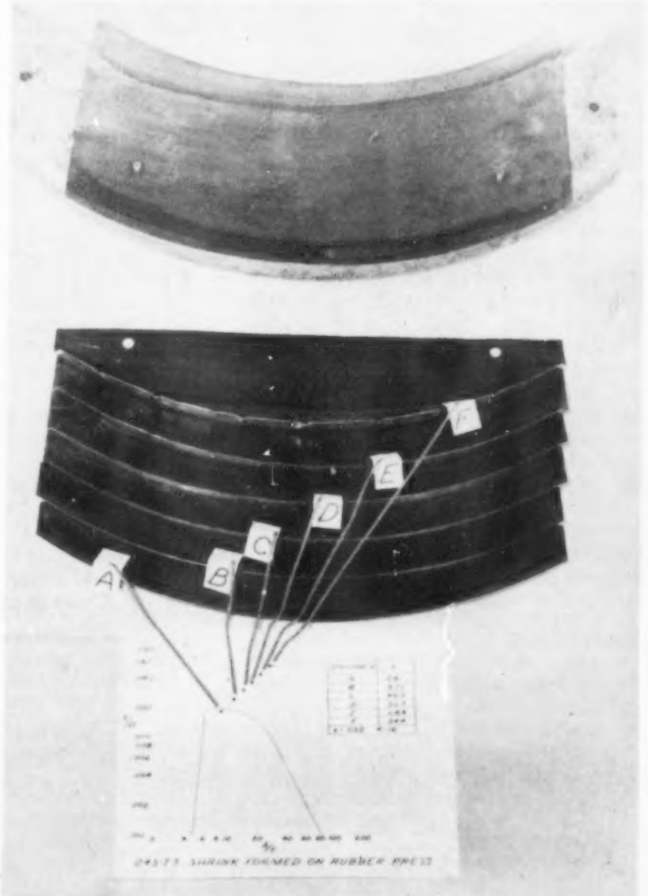


Fig. 6.—24S-T3 shrink-formed on a rubber press

part so that the part would spring back to the desired shape after it had been formed over the developed die. This method has never proved satisfactory for the following reasons: (1) Material variations such as thickness and strength were sufficient to make die development impossible. (The yield strength of 4908 titanium, for instance, varies as much as 45 per cent of the minimum guaranteed). (2) Complexity of the geometry of parts makes it practically impossible to isolate the effect that each has on springback. (3) Normal methods of forming with various operators and machines are so different as to cause considerable variations in springback.

The most popular method of controlling springback has been by hand-working. It is readily admitted that this procedure is far from a production method, but it has been used extensively because no better method has been found to replace it. It has been estimated that as much as 50 to 60 per cent of the total production detail effort in producing parts in aircraft companies is directed toward hand-working.

Considerable effort is expended for instance on hand-working the most widely used material in the aircraft industry, 7075 aluminium. This material is usually formed in the annealed condition. Little difficulty is encountered, but, in most forming operations, some springback is evident. During the quenching operation, however, considerable distortion takes place while very little change takes place during the ageing process to the T-6 condition. Whether the part is reformed in the W or T-6 condition, it usually requires handworking for the final shaping.

Some parts such as contoured hat sections and channels with return flanges, double curved skins, and beaded panels are very difficult, if not impossible, to hand-work into the final shape. Difficult contoured structural members are usually finish formed with a hammer on a hand straightening fixture.

Another method of controlling springback for particular types of parts is incremental forming. This method is based upon a localized and progressive plastic deformation. The two principal manners by which this type of forming is accomplished is by roll forming and Anderson skin forming.

The former is limited to forming structural members and sheet into constant radius curvatures. The structural members that can be formed by this method are very limited because of the tendency for buckling in the unsupported area while sheet rolling has no practical limitations. This is not a production method as it usually requires a number of passes to obtain the correct shape.

The Anderson method is a type of incremental forming for fabricating double-curved sheet. The process can be visualized by drawing a sheet of paper over the round corner of a table. Parts formed in this manner are fairly consistent and springback variations due to material properties variation are relatively small because of the small curvature of such parts. This is a very good production method, but it is limited to only small curvatures.

A third method of controlling springback may be termed elevated temperature creep forming. Unlike hand-working and the Anderson method, creep forming may be utilized to remove buckling and distortions, thus raising the formability limits of a material considerably.

Creep in metals is generally illustrated with a graph as shown in Fig. 7. Creep is a term applied to metals where flow is attained at rates slower than slip. Provided the applied stress is sufficiently high, there will be three stages of flow for a given temperature: (1) primary creep, where the flow begins rapidly but later slows down, (2) secondary creep: when the part becomes adjusted to the load, and a steady deformation persists, and (3) tertiary creep, evidenced by a rapid increase in flow until failure occurs.

Creep is a very obscure phenomenon, but one theory relates it to the dislocation theory in metals([5]). A complete description of this theory is beyond the scope of this report; however, a dislocation can be thought of as a portion of an extra atomic spacing sandwiched between two mating rows of atoms as shown in Fig. 8. The result is that slip (plastic flow) along the slip plane noted is much easier than would be the case if no dislocations were present.

Creep in metals is thus dependent upon the level

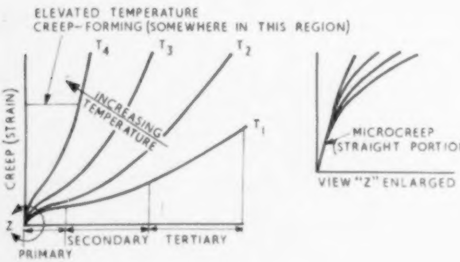
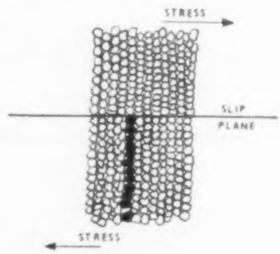


Fig. 7 (left).—Typical creep curves for metals (constant applied stress)

Fig. 8 (right).—Diagram of dislocation



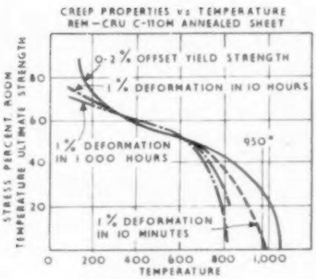
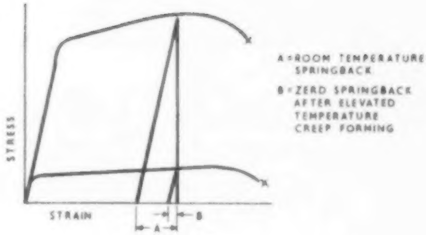


Fig. 9 (left).—Stress-temperature diagram

Fig. 10 (right).—Diagram illustrating disappearance of springback



of the applied stress, time, temperature, and the number of dislocations present. In elevated temperature creep forming, the applied stresses are generally low and the time is of a short duration (usually less than 10 minutes). The number of dislocations is dependent upon the alloy and, consequently, the susceptibility for elevated temperature creep forming is dependent upon the material.

Temperature acts to increase the thermal fluctuations of the atoms (kinetic energy gain) resulting in the necessary activation energy for generating new dislocations. Under a constant load, such as in a hot mechanical forming die, microcreep is initiated by dislocations already present in the material; however, the material is allowed to creep further by the additional dislocations formed by the thermal energy. Finally, equilibrium is reached after sufficient strain has occurred to relieve the applied stress to a negligible quantity.

What proportion of the total strain occurring in elevated temperature creep forming can be attributed to microcreep and what proportion to secondary creep is purely speculation. At any rate, the amount of recoverable creep is negligible provided the temperature and time is sufficient. This permanent deformation has been found to occur on AMS 4908 titanium in 6 to 10 minutes at 950°F (510° C.) For the same periods of time, the following temperatures have been tentatively found to produce permanent creep in the following materials:

1. 6 Al.-4V titanium (annealed) —648° C.
2. HK31-H24 magnesium-thorium —343° C.
3. 17-7 PH steel (fully aged)—(only around 50 per cent susceptible at 565° C.)
4. 2024-T81 (fully aged) —343° C.

This type of creep forming can be visualized with the aid of a stress-temperature diagram as shown in Fig. 9([6]).

The curves represent the relative amount of stress necessary to produce (1) 1 per cent deformation in 1,000 hours, (2) 1 per cent deformation in 10 hours, and (3) 1 per cent deformation in 10 minutes (estimated). It should be noted that only around 5 per cent of the room temperature ultimate stress is needed to produce 1 per cent deformation in 10 minutes at 950° F (510° C.) This is strictly an estimate, but it presents a qualitative picture of what is necessary to produce elevated temperature creep forming.

Fig. 10 illustrates the disappearance of springback as brought out on preceeding pages.

The upper curve represents a room temperature stress strain-curve resulting in an elastic recovery or springback "A" provided forming is at room temperature. The lower curve illustrates the low stress level approached in elevated temperature creep forming resulting in negligible springback "B".

This type of forming can have many applications such as: (1) contoured structural members, (2) beaded panels, (3) double curved sheet, and (4) recessed parts. Other types such as deep drawn parts are excluded because elevated temperature creep forming is intended primarily as a means of removing springback and distortions rather than increasing elongation.

The principal applications at C.V.A. have been on forming AMS 4908 and 4901 titanium structural members ([7], [8], [9]). The benefits to tooling and production have been considerable. Practically all hand-working that would normally be necessary to obtain the desired shape has been eliminated.

Future investigations will be concentrated primarily on beaded panels, double curved skins, and recessed parts.

Creep forming, in general, increases formability around six to the fold; however, there are still limitations of the same sort as in conventional forming. For instance, most structural members will be limited by the shrink flange type curve shown in the third picture in the appendix([8]). Beaded panel formability will be limited to the type of curve presented in the previous section on "Springback and Buckling"; however, the curves will be transferred much more favourably to the upper right side of the graph.

Double-curved skin forming is expected to be limited according to a graph as shown in Fig. 11.

Buckling is still noticed to be the limiting

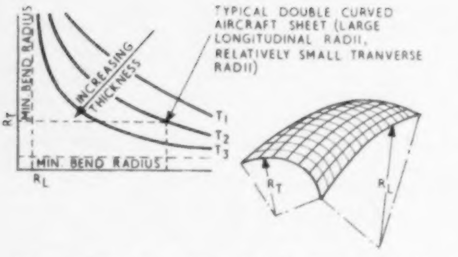


Fig. 11.—Forming in a mechanical die from a flat blank

parameter as indicated by better formability with increasing thickness of material. A typical double-curved aircraft sheet is shown as a dot on the graph with a large longitudinal radius and a small transverse radius.

Finally, limitations to elevated temperature creep forming will be associated with the metallurgy of the material. The consideration here is what effect temperature exposure has on the mechanical properties. A typical graph representing this effect is shown in Fig. 12.

It can be seen that the loss in strength for this material after an exposure of 10 minutes for the two temperatures T_1 and T_2 is not appreciable whereas the higher temperatures T_3 and T_4 result in a somewhat higher loss in strength. Another metallurgical consideration should also include age embrittlement, although the sensitivity of most materials in this respect is not very high for such short exposure times.

Conclusions and Recommendations

It has been shown that the principal factor in selecting new materials for airframe application has been structural efficiency. It is very doubtful, however, that many engineers in the design section realize the manufacturing problems and limitations associated with the production fabrication of aircraft.

It has been the popular conception in engineering design that formability was related almost entirely to the elongation of a material. This is true for parts that are severely strained in highly localized areas such as brake forming, deep drawing, dimpling, etc. It is understandable that this would be the case because design is directly concerned with the ability of manufacturing to produce small bend radii and good dimples.

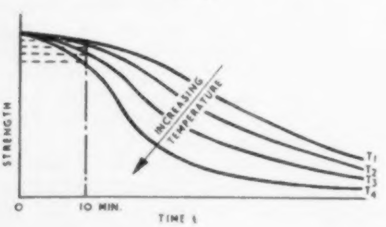
Except for the few cases mentioned above, however, elongation plays a minor role in formability. The other part of formability in manufacturing is related to producibility. How can parts be formed in a production manner with a minimum of hand working? Springback, buckling, and distortions have long played the chief role in limiting the producibility of thin-sheet aircraft parts. Until recently, the principal methods for handling springback has been die development and hand-working. The former, however, is without control, so that handworking has been relied upon by most airframe producers to finish shape the parts.

Handworking, however, is likely to prove inadequate when applied to the new high strength materials for two reasons: (1) springback and distortions of high strength materials are excessive, and (2) the high strength materials are more difficult to hand work.

It is concluded, therefore, that elevated temperature creep forming will be the chief method of controlling springback and distortions. From a manufacturing standpoint, the susceptibility of an alloy to this type of hot forming will be the principal criterion for the selection of materials for airframes. If the temperature required for creep forming is beyond the practical metallurgical limits for a material, it is very doubtful that manufacturing would advocate its acceptance for use.

Creep forming can be applied to most parts where mated dies can be utilized for forming. The principal modes of heating have been with electrical resistance heated cartridges inserted in mechanical dies. Heating in the future might possibly utilize a means such as hot fluid so that die costs could be reduced to approximately half of the current costs.

Fig. 12.—Short-time room-temperature strength after short-time exposure at elevated temperatures for a given alloy



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Quantitative Assessment of

DEEP-DRAWING and STRETCH-FORMING QUALITIES—2*

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(*Continued from page* 674, *September*, 1961)

Cup-drawing Tests

TEST rigs for cup-drawing tests vary from hand-operated fly presses with no accurate control of punch load or speed to elaborate electrohydraulic units with full instrumentation. The simplest test is to determine the depth of cup which can be drawn from a circular blank of standard diameter using standard tools, speed, lubrication, and sheet-holder pressure. The depth of cup at fracture to blank diameter ratio is sometimes quoted for this type of test but it is essential to compare such ratios only when they apply to the same sheet thickness and the same tools. An improvement on this is to determine the critical blank diameter which is the largest diameter blank which will just form a complete cup without fracture, through standard tools. The result is often expressed in terms of the limiting drawing ratio, given by the ratio, maximum blank diameter : punch diameter. A further elaboration of the cup-drawing test is to plot punch pressure against cup depth curves for comparison. The test also allows investigation of many of the tool and drawing condition variables.

* This article is based on two lectures included in a special course on "The Metallurgy of Deep Drawing and Pressing", held at the Department of Metallurgy, Birmingham College of Advanced Technology.

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A number of elaborations of the above basic principles have been specified in reasonable detail but the tests most commonly encountered are the Swift cup-drawing test and the Erichsen cup-drawing test.

The Swift Test

The test which evolved from the work of *Professor Swift* has been described in detail[23]. It determines the limiting drawing ratio for a cup drawn from sheet beneath a blankholder which subjects the sheet to a specified blankholder load but which allows sliding of the sheet between holder and die. Two types of punches are used, one flat-ended to simulate deep-drawing conditions and the other hemi-spherically ended to simulate deep drawing involving a considerable degree of stretch-forming. In addition each of these types is made in two sizes. Appropriate ring dies are recommended for each punch depending on the thickness of sheet to be pressed. The general principle governing the punch die clearance, over and above the thickness of the sheet to allow for thickening of the blank during drawing, is that it should lie between 40 per cent and 100 per cent of the sheet thickness. The tentatively recommended tool sizes are given in Table I[23].

TABLE I

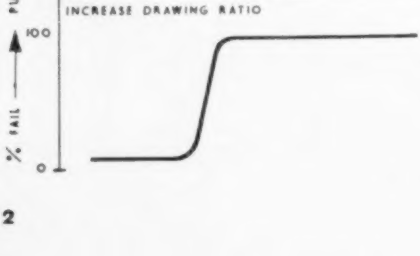
Punch		Die		
Diameter	Head radius	Sheet thickness	Die diameter	Die radius
32 ± 0.05	4.5 ± 0.1	0.30 to 0.43	33.20 ± 0.05	4.3 ± 0.1
		0.43 to 0.61	33.72 ± 0.05	6.1 ± 0.1
		0.61 to 0.87	34.44 ± 0.05	8.7 ± 0.1
		0.87 to 1.24	35.48 ± 0.05	12.4 ± 0.1
50 ± 0.05	5.0 ± 0.1	0.45 to 0.64	51.89 ± 0.05	7.1 ± 0.1
		0.64 to 0.91	52.56 ± 0.05	9.1 ± 0.1
		0.91 to 1.30	53.64 ± 0.05	13.0 ± 0.1
		1.30 to 1.86	55.20 ± 0.05	18.6 ± 0.1

All dimensions in millimetres.

Blanks should be sheared or punched out oversize and then turned or ground to size to eliminate work-hardening effects. The tentative specification details a drawing lubricant which for ferrous materials is loaded to the extent of 10 per cent with a chlorinated paraffin wax. Lubrication is by immersion of the blank for not less than one minute in the lubricant and draining of excess lubricant immediately before testing. The blank-holding load should be 50 to 75 per cent above the load at which wrinkles cease to be visible on a drawn cup and although it is not very critical within this range, comparative tests should be made with a blankholder pressure reproductibility of ±5 per cent. With a little experience, suitable blankholder pressures can be selected for groups of deep-drawing materials in various thickness ranges without having to resort to an actual determination of wrinkling tendency for every test.

The procedure for accurately determining the limiting drawing ratio in cup-drawing tests is rather lengthy. There are two approaches. In the first, single blanks of various diameters near to the suspected critical blank diameter are tested by a bracketing method to find one which is too large and one which is too small. The mean of these is then tested and if it fails the lower bracket is examined ; otherwise the upper bracket is examined. The process is repeated until the likely blank size has been found. The blanks for the Swift test are normally made in increments of diameters which will give increments of 0.025 in the limiting drawing ratio ; increments of 0.05 in. for the 2-in. (50-mm.) punch for example. Similarly, in the Erichsen cup-drawing test, one-millimetre increments are used. The second method of assessing the critical blank size relies on the fact that the punch pressure, necessary to draw the cup completely, rises linearly

Fig. 13.—An exaggerated representation of how uncertainty arises in estimating limiting drawing ratios



with increasing blank diameter up to the critical blank diameter and further increases in blank diameter beyond this require a substantially constant punch load to fracture. If the slope of the curve of punch load plotted against blank diameter is determined, together with the fracture load, extrapolation to the point of intersection gives the critical blank diameter. The accuracy of this method increases with the number of blanks tested. The uncertainty in the critical blank diameter obtained in this way is illustrated in Fig. 13. Whichever method is used to determine the critical blank diameter, it should be confirmed in accurate work by repeated tests at the blank diameters adjacent to the approximate maximum blank diameter. The Swift test recommendations suggest five repeat tests at each of these diameters. Obviously this requires considerable work and makes the test a research or referee method rather than a routine test. *Svahn*([26]), studied statistically the dispersion in testing values using 3, 6, 10 and 50 test blanks to determine the limiting drawing ratio under carefully controlled cup-forming test conditions on mild steel, stainless steel, brass and aluminium. He concluded that an accuracy of 0.5 per cent on blank diameter was possible using six blanks and a great increase in the number of blanks was required to better this significantly.

Much detailed development work has been done to assess the influence of the many variables in the so-called "simple" cup-forming test. The work of *Swift* and his co-workers([11], [23], [24], [25], [28]), of *Svahn*([26]), and of *Zaat*([27])*, provide a basis for study of this field.

Willis([25]), in reviewing Swift's work demonstrates how Swift's theoretical treatment of the deep-drawing process was sufficiently accurate to enable forecasts to be made of the amount of work, the punch load, the degree of thickening of the blank and other factors involved, to an accuracy of 1 per cent. The component operations considered in deducing this theory were drawing the flange in over the face of the die ; bending of material over the die-entry radius and its subsequent unbending to form the cup wall, both under tension ; the stretching and thinning of the cup walls and the stretching of the blank over the punch profile. Bending the material over the die-entry radius under tension contributes to the thinning process. The amount of thinning increases with the sharpness of curvature, the thickness of the metal, and the amount of applied tension, and with decreasing strain-hardening capacity. Unbending also produces thinning although the effect is less than that caused by the original bending([24]). This is also reflected in the fact that increasing the blankholder pressure, within reasonable limits, although not

* This paper will be published in a future issue of *Sheet Metal Industries*.

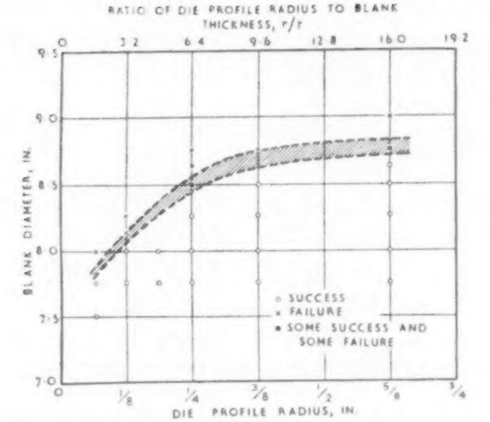


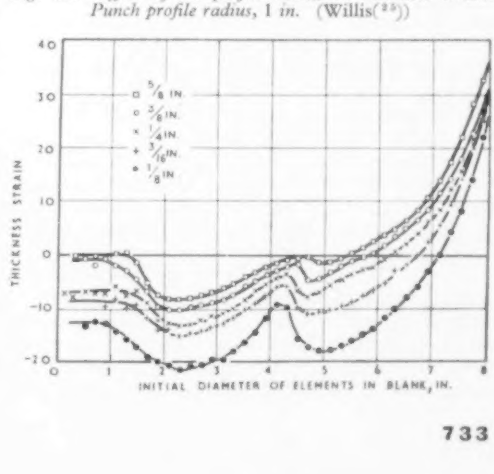
Fig. 14.—*Effect of die profile on drawing capacity* (Willis[25])

greatly altering the punch load, produces a slightly thinner walled cup. The range over which blankholder pressure may be varied, without detriment to the limiting drawing ratio and excessive increases in punch load, has been the subject of slight differences of opinion. When drawing thick blanks, a pressure plate may not be needed to prevent wrinkling although its use enables a larger blank to be drawn. When a blank is prone to wrinkling the blankholder pressure, in preventing wrinkling, enables a larger blank to be drawn but if the pressure is excessive the critical blank diameter again decreases. *Chapman* and *Wallace*[29], are of the opinion that the blankholder pressure should be adjusted to a value of 50 per cent above that which just prevents wrinkling and a further increase beyond this value reduces the limiting drawing ratio. *Swift*[28], has suggested that blankholder pressure up to at least 400 per cent in excess of the minimum required to prevent wrinkling is permissible and mean pressures over the flange of about 400 lb. per sq. in. for steel and 250 lb. per sq. in. for aluminium are satisfactory. The important thing is to ensure that the blankholder pressure is not excessive and having selected a satisfactory pressure, to maintain it at a constant level for comparable tests. However, when extreme changes in blank diameter are made, it is advisable to make allowances for the fact that the load per unit area of flange will increase considerably for small blanks compared with large blanks under a constant total blankholder load.

Over a limited range, increasing the die entry profile radius increases the critical blank diameter[25, 26], but great increases in this radius produce only slight additional benefit. This is illustrated by Fig. 14. A disadvantage of a large die-entry radius is that the influence of the blankholder can be exerted only up to the edge of the die-entry mouth and large die entry radii leave the sheet unrestrained to a greater extent than small profile radii. From Fig. 14, *Swift* has suggested a reasonable compromise, for die entry profile radius, of 10 times the sheet thickness. Increasing the profile radius also evens out variations in cup thickness and reduces the severity of necking, as shown in Fig. 15, using a hemispherically ended punch. Increasing the profile radius also reduces maximum punch load and reduces the total work, Fig. 16. It will be seen from the table of recommended tool dimensions for the Swift test that the die entry radius for each sheet thickness range is 10 to 14.3 times the sheet thickness, except for the 0.45-to 0.64-mm. sheet range using the 50-mm. diameter punch. This particular range uses a die clearance of 55 to 110 per cent of sheet thickness and the die entry radius is 11 to 15.8 times the sheet thickness, for reasons given in the tentative specification[23].

As the punch profile is changed progressively from a flat-ended punch with sharp profile radius to a hemispherically ended one, the two necking regions which form on or near the cup bottom radius during drawing become less pronounced. On the other hand, thinning at the centre of the base becomes more severe as is shown for mild steel in Fig. 17. *Chapman* and *Wallace*[29], have shown that the limiting drawing ratio does not vary with punch diameter, provided the ratio of sheet thickness to punch diameter is constant. Results obtained with punch diameters less than 1¼ inches showed anomalies so a punch of 1¼ inches or more in diameter is preferred. If the punch diameter is increased while maintaining the sheet thickness constant, the limiting drawing ratio decreases. This is attributed to the greater proportionate effect of surface friction at lower values of the ratio, material thickness : punch diameter. Combining

Fig. 15.—*Effect of die profile radius on thickness strain. Punch profile radius,* 1 *in.* (Willis[25])



the effects of punch profile radius and punch diameter, *Svahn* has shown[26], that the limiting drawing ratio decreases with decreasing punch profile radius and the effect of decreasing punch profile radius is more damaging with increasing punch diameter.

The clearance between punch and die for the Swift test is between 40 and 100 per cent above the sheet thickness. *Svahn*[26], has suggested that the limiting drawing ratio is unaffected by a variation of punch to die clearance above the sheet thickness of from zero to 100 per cent. It should be noted that a clearance between the punch and die equal to the original sheet thickness, *i.e.*, an excess clearance of zero, will result in some ironing of the cup wall due to the thickening of the original sheet as it crowds into the die mouth. *Zaat*,[27] states that the clearance must be large enough to allow free movement of sheet between punch and die, which implies a minimum excess of about 30 per cent.

Regarding the effect of speed of testing, *Svahn*[26], states that a variation in punch speed above about 3 mm. per sec. up to 154 mm. per sec. (30 ft. min.) had no influence on limiting drawing ratio, but at very low speeds, the limiting drawing ratio tends to increase slightly. The tentative specification for the Swift test[23], states that the drawing speed should be maintained reasonable constant and should normally be below 35 mm. per sec. (7 ft. per min.) In discussing speed effects it is very difficult to distinguish the effect of speed *per se* from the indirect effect of speed on lubrication. The combined

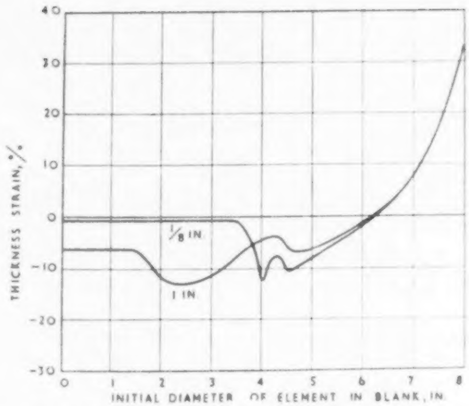
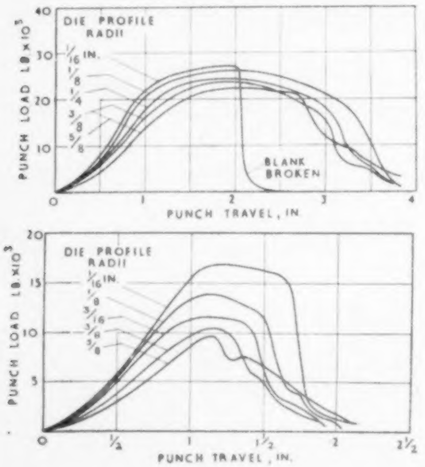


Fig. 17.—Effect on punch profile on thickness strain distribution in drawing annealed mild steel. (Willis[25])

effects of lubrication and punch speed in the range, 10 to 90 ft. per min. (50 to 450 mm. per sec.) have been investigated by *Coupland* and *Wilson*[67], using a Swift cup-drawing press. Within this speed range the temperature of the deforming blank will rise appreciably and the flow stress will be reduced. Because the drawing zone rather than the stretch-forming zone over the end of the punch is affected, this will tend to improve drawing capacity. On the other hand, the increase in temperature will also reduce the efficiency of a liquid lubricant. Annealed 70/30 brass lubricated with a thin film of graphite showed no detectable speed effect but when drawn with liquid lubricants the effectiveness of the lubricant changed with drawing speed. An increased speed increased lubricant effectiveness on the punch side, which was reflected in a decreased limiting drawing ratio with a round-nosed punch because of easier stretching. The effectiveness was also increased on the die side which resulted in an increased limiting drawing ratio with a flat-nosed punch. With both steel and brass the highest limiting drawing ratio was obtained when the blanks were lubricated on the die side only, presumably because the punch is then able to restrain the material in contact with it from excessive stretching. Tests made using mineral oils showed that lubrication improved with increased lubricant viscosity. Thus the effects of increased lubricant viscosity on drawing capacity are similar to the effects of increased drawing speeds. Work by *Wallace*[30], confirms this, in showing that drawing ratio increases with speed using mineral oil due to an increased hydrodynamic effect maintaining full film lubrication, while at low speeds the oil tends to be squeezed out. On the other hand, using a typical boundary lubricant such as calcium oleate, *Wallace* showed the limiting drawing ratio decreased with increasing speed because local

Fig. 16.—Effect of die profile radius on punch load/punch travel. Top diagram, using positive blank pressure on an 8-in. diameter blank and hemispherically-ended punch. Lower diagram using positive clearance blank-holder on a 6-in. diameter blank and hemispherically-ended punch. (Willis[25])



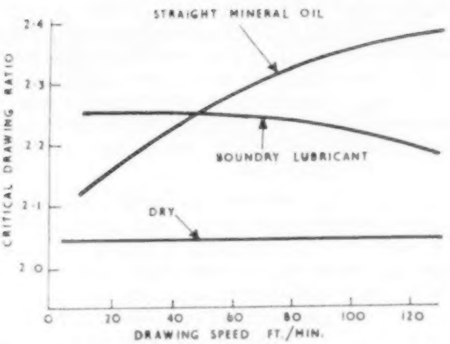


Fig. 18.—Effect of speed and lubrication on limiting drawing ratio. (Wallace[30])

heating broke down the lubricant partially. In the absence of a lubricant, the drawing ratio did not vary with drawing speed as is shown in Fig. 18. *Coupland* and *Wilson*[67], point out the difficulty which arises when attempts are made to assess commercial drawing behaviour from standardized tests using conditions of speed and lubrication quite different from those used in the press-shop. Additionally, lubrication over the punch is necessary if maximum stretch-forming ability is to be measured but unnecessary to achieve good deep drawability. *Witton* and *Mear*[31], investigating the influence of tool and sheet surface finish on the results of the Swift test using a 2-in. diameter punch, showed that aluminium gave a better limiting drawing ratio when drawn with a rough punch and smooth die. They also showed that variation in roughness of aluminium and brass test blanks in the range 0 to 20μ-in affected the drawing ratio very little but rough steel tended to draw better than smooth. As a result of this work, *Witton* and *Mear*, recommend that the tool roughness range for the Swift test should be reduced from 0 to 20μ-in. centre-line average[23] to 0 to 10μ-in. centre-line average in order to improve correlation between different Swift presses. They point out that tungsten-carbide tooling would be advantageous in keeping surface wear to levels within the acceptable finish range.

Sufficient has been discussed above, though little enough compared with the scale of the original work and work still required, to indicate the complexity of the problem of producing a satisfactory simulative cup-drawing test. Arising from this approach there are two possibilities. First, if every variable in the process is known it should be possible to derive an accurate relationship between all the variables and a function of drawability. This relationship will be exceptionally complicated. The formulae derived by *Swift*, which assume some simplifications, are too complex for everyday industrial use, although they can be used, if time and skill is available, to predict approximately material performance in the press or the press capacity required for a given component. The second approach is to so carefully control the variables of a simulative testing procedure that the test value gives a direct assessment of the performance of a given sheet under the press. This type of approach has been detailed by *Zaat*[27] who concludes that to differentiate intrinsic sheet quality it is necessary to standardize testing conditions to an advanced degree. If it is recognized that many variables affecting the limiting drawing ratio in a cup-drawing test are continuous, then every attempt should be made to produce smooth relationships between the various tool dimensions and sheet thicknesses. In order to do this, among other relationships, *Zaat* claims the die diameter should be a linear function of punch diameter and sheet thickness; die profile radius must be proportional to sheet thickness; and punch profile radius must be a linear function of both the punch diameter and the sheet thickness. Finally, *Zaat* prefers to use the "cup-head limiting drawing ratio", which he defines as

$$\frac{\text{Limiting diameter of blank}}{\text{Internal die diameter} + \text{original sheet thickness}},$$

as the measure of drawability. It is said to be a more accurate measure than the conventional limiting drawing ratio and the difference between the two may be as much as 7 per cent, the difference being a function of punch diameter and sheet thickness.

The argument put forward by *Zaat* is acceptable in principle but to put it into practice in a test would require a very large number of die and punch sets, each set being used for a small range of sheet thickness. This is assuming the use of only one punch diameter, but the punch profile would vary gradually from one sheet thickness range to the next. If two basic punch diameters are considered, as in the Swift test, the tool requirements are doubled. On this basis, the Swift test tool dimensions may be regarded as a compromise between the theoretical requirement of many tools and a test involving only a single set of tools. Thus the die diameter and profile radius in the Swift test vary linearly with the mean sheet thickness in four ranges for the two punch diameters. Punch profile radius does increase slightly in changing from the 32-mm. to the 50-mm. punch, but each punch profile radius remains constant with respect to sheet thickness.

The Erichsen Cup-drawing Test

Having discussed the variables in a cup-forming test in terms of the Swift test it is now appropriate to discuss the Erichsen version of the test which has in fact been in existence longer than the Swift test. The basic principles of forming the cup and

TABLE II

Sheet thickness		Die profile radius, mm.	Excess clearance / Sheet thickness (per cent)	Die profile rad. / Sheet thickness
mm.	in.			
0.20	0.008	3	25.00	15.00
0.40	0.016	3	25.00	7.50
0.60	0.024	3	25.00	5.00
0.80	0.032	3	18.75	3.75
1.00	0.039	3	20.00	3.00
1.20	0.047	3	20.83	2.50
1.40	0.056	3	21.43	2.14
1.60	0.063	3	18.75	1.87
1.80	0.071	3	19.44	1.67
2.00	0.079	3	20.00	1.50
2.20	0.087	4	18.18	1.82
2.40	0.095	4	20.83	1.67
2.60	0.102	5	19.23	1.92
2.80	0.110	5	19.64	1.78
3.00	0.118	6	20.00	2.00

measuring the drawability are the same as for the Swift test, but there are differences in tool dimensions. In the first place, only one punch diameter is used, 33 mm., and the punch profile radius is 4.5 mm., as in the equivalent Swift test punch. As far as the present author is aware, no firm recommendations have been made as to the maximum range of sheet thicknesses to be represented by each die in the Erichsen test, but the design of the dies varies continuously according to sheet thickness as shown in Table II which uses only a sample of the available die sizes as an illustration.

It is immediately apparent that the die profile radius is small compared with that used in the Swift test and as a result the ratio of die profile : sheet thickness varies from 1.5 to about 5 over the main part of the range as compared with 10 to 14.3 in the Swift test. The other main difference is that the excess clearance over sheet thickness between punch and die in the Erichsen cup-drawing test is far more constant than in the Swift test because of the larger number of dies available. It varies between 15 and 25 per cent of the sheet thickness as compared with 40 to 100 per cent for the Swift test. As a rough guide, an Erichsen deep-drawn cup will finish with an average wall thickness the same as the original sheet thickness and a small amount of ironing will have taken place in zones where thickening had occurred. Thus, the Erichsen version of the cup-drawing test is generally "more severe" than the Swift test, and the Erichsen limiting drawing ratio should in the majority of cases be slightly smaller than that obtained in the Swift test. There are exceptions to this in that there are some sheet conditions when the blank is able to negotiate the tight die-entry radius of the Erichsen die without failure and also benefit from a slight degree of ironing in the wall. The limiting drawing ratio may then be higher than that given by the Swift test. The argument for the Erichsen version of the test is that in producing a cup with a wall the same thickness as the sheet and allowing in most cases a small degree of ironing the test is a closer simulation of industrial deep-drawing conditions than a test which allows free movement between punch and die.

Whereas the possibility of using a round-nosed punch is written into the tentative specification for the Swift test to represent a degree of stretch-forming, this is not a normal part of the Erichsen test but there is no reason to prevent a round-nosed punch being used successfully in the Erichsen test. There is an extension of the test which is fully specified and that is the second draw test. This takes a cup drawn from a critical blank diameter and draws it down to a smaller diameter, without interstage annealing, giving a further reduction of about 20 per cent. The important point is that the cup should fail in the redraw and the depth of redraw punch penetration is said to be a measure of the ductility remaining in the first stage cup. It should therefore help to discriminate between two sheets having the same critical blank diameter. The usefulness of a redraw test has been demonstrated by *Gwyer* and *Varley*([32]), who showed that a two-stage draw may reveal important differences in the deep-drawing properties of sheet aluminium which are not revealed by a single draw. Such tests also determine the most suitable ratio of first- and second-stage draws. *Willis*([25]), in describing Swift's work also discusses some aspects of two-stage drawing which are pertinent to a redraw test. A flat-bottom cup is more satisfactory for subsequent redrawing. This is partly due to the fact that the flat bottom of the cup is generally thicker than the equivalent round-bottom cup. The position of the local necking which occurs over the sharper profile of a flat nosed punch is away from the position of local necking generated by the redraw punch and consequently is not critical. It was found that the deepest combined drawing ratio occurred when the first stage cup was drawn as deeply as possible but materials which can be drawn very well in the cup-forming stage generally give no deeper cup after redrawing than material having only a moderate initial cup-forming capacity. Thus, substantial work-hardening ability which is normally valuable in initial cup forming can make a material less suitable for redrawing. It follows then, that the order of merit for materials in the cup-forming stage often will not apply to the same materials sorted on a basis of their redraw ability. Generally, the redrawing ratio varies inversely with the initial drawing ratio due to the increased work on the larger initial blank causing greater work-hardening which, in turn, increases the punch load necessary for redrawing. The above remarks apply

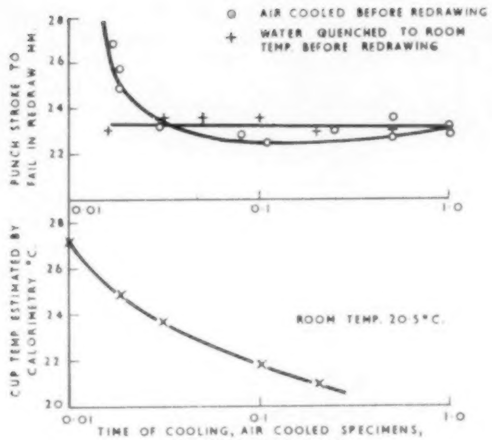


Fig. 19.—Redraw depth to failure of similar 70/30 brass cups compared with time elapsed between cup forming and redrawing and with estimated temperature at the time of redrawing

only to direct redrawing without interstage annealing. Reverse redrawing ability could be tested but is beyond the scope of the present review. Naturally, annealing distinctly improves redrawability, so does redrawing at a higher temperature without annealing. It is important to appreciate this when conducting redraw tests, because if the temperature of the initial cups varies, as it may easily do, owing to varying degrees of work heating and varying degrees of cooling between first and second stage, then the results will not be comparable. Fig. 19 illustrates how the redraw depth to failure of a number of similar cups in 70/30 brass decreases appreciably with increasing time between the cup-forming and the redrawing operation. On the same time scale, the average temperature of the cups is plotted as a result of calorimetry experiments. It will be seen that an average increase in temperature of only a few degrees produces a significant increase in redrawability.

There is little doubt that redraw tests have a useful part to play, either in assessing the residual ductility in a cup formed from a critical blank diameter which is the object of the Erichsen second-stage test, or in studying redrawability for its own sake. Considerably more work is required, however, on the specification of a redraw test before either of these objectives can be achieved with complete satisfaction.

Directionality Testing

Before leaving the subject of the simple cup-forming test, it is appropriate to mention its use in assessing directionality of sheet material intended for deep drawing. Briefly, a cup is drawn from a specimen blank with the object of assessing directionality from the height of the ears produced on the wall of the cup and their relationship with the direction of rolling of the original sheet. Observing the position of the ears with respect to rolling direction is a simple matter and requires very little by way of test specification but quantitative comparison of directionality on the basis of ear height is influenced by several variables. No completely satisfactory and widely accepted specification exists for this type of test. Ear height may be expected to increase with increase in the ratio of blank diameter : punch diameter and with increasing punch profile radius because in both cases larger areas of the blank are brought into a position to contribute to the cup wall and to the formation of ears. On the other hand, increasing degrees of ironing would be expected to decrease ear height because ironing would act on the thicker material at the base of the troughs in preference to the thinner material of the ears.

The Hole-expanding Cup Test

The simple cup-drawing test has been modified in several ways, including the drawing of a cup from a blank with a hole in it so that the hole appears in the base of the cup. The originators of this test were *Siebel* and *Pomp*(33), at the Kaiser Wilhelm Institute, the initials of which, K.W.I., are often used to distinguish the test.

Originally, the specimen for this test was 90 mm. square and a 12 mm. diameter hole was reamered at its centre. The blank was partly drawn into a cup, using a 40-mm. diameter punch with 5-mm. profile radius moving into a radiused ring die which allowed sufficient excess clearance to avoid ironing. The cup was drawn to the point where radial cracks appeared to start from the edge of the hole and the K.W.I. value was then given by the percentage increase in the average diameter of the hole. At the end of the test, the hole is not likely to be circular due to possible directionality in the sheet leading to non-uniform radial flow. A square blank with no such directionality will flow more easily from the four flat edges than it will from the corners. In order to eliminate the restraining influence of the corners it is now the practice to use circular blanks although they are slightly more

TABLE III

Punch dia. (mm.)	Hole dia. (mm.)	Die dia. (mm.)	Blank dia. (mm.)	Blank thickness (mm.)
55	16.5	61	>90	>2
40	12.0	44	>70	>2
25	7.5	27	<70	0.2 to 1.0
12	4.0	14	>25	0.2 to 1.0

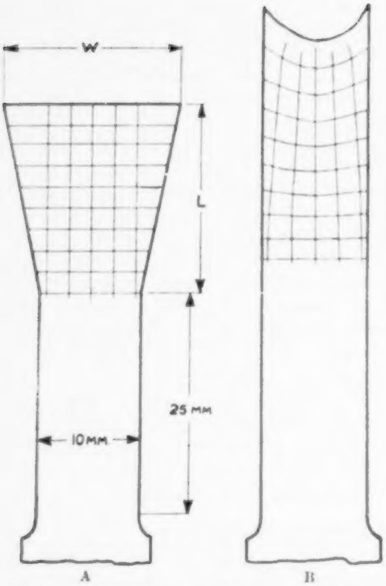


Fig. 20.—Specimen used in Sachs' wedge-drawing test: (a) before testing; and (b) after testing

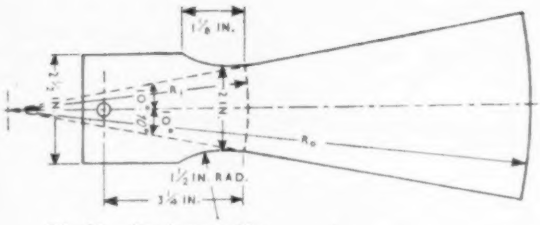
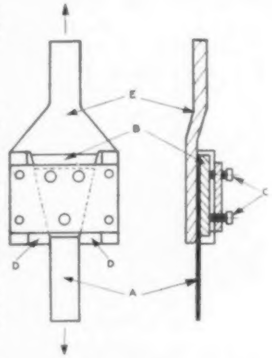


Fig. 21.—Specimen used by Swift in his wedge-drawing test[25]

Fig. 22.—Diagram illustrating the die used in the original wedge-drawing test. (A) Specimen, the end of the parallel part to be gripped in the lower jaws of the tensile testing machine (B) Plate to prevent the specimen buckling. (C) Screws to adjust plate B. (D) Side pieces forming tapered die. (E) Prong to be gripped in upper jaws of testing machine



troublesome to prepare. It is also necessary to prepare the edge of the central hole very carefully and consistently. In order to test narrow and thin sheet material the original test dimensions have been supplemented with alternatives as shown in Table III.

It was originally considered that the K.W.I. test measured the ductility of the metal situated at the periphery of the hole. However, even if the hole is prepared very carefully with minimum work-hardening at the edge, the cracks do not always initiate at the edge itself but at a small distance from the edge[34]. This cannot be explained only on the assumption that preparing the hole has produced work-hardening because of the percentage of samples where the crack obviously did not initiate at the hole fell with increasing hole diameter to punch diameter ratio. It seems likely, therefore, that the K.W.I. test does not guarantee fracture at the edge of the hole and the position where the crack begins depends on the strain pattern in the blank as whole, which is, in turn, dependent on the test variables and the sheet properties. *G. de Witte*[34], uses the following argument to show that this might be expected. If no hole existed in the blank, the cup would fail over the punch profile radius. If a sufficiently small hole is introduced it would not alter this pattern of failure. As the hole is enlarged, the point of fracture initiation would be expected to move towards the hole but not in a discontinuous fashion.

What then does the K.W.I. test measure? One might expect it to assess materials in terms of their ability to form deep pressings which also have holes in the stretch-forming zones. A number of engineering pressings could be placed in this category and the K.W.I. test might well simulate them better than a simple cup test. More fundamentally, the hole expanding test subjects the blank to shrink-flanging under the blankholder and die face, stretch flanging over the punch head and some bending and unbending. If the stretch flanging can be made the dominant part of the test, then the test results may be applicable to pressings where stretch-flanging is important but not necessarily carrying a central cut-away zone as does the actual test-piece.

Wedge-drawing Tests

Mention of shrink-flanging above is a suitable introduction to wedge-drawing tests. The objective of such tests has been to impose compressive stresses in the width of a strip specimen during a tensile test. One of the distinguishing features of pure deep drawing is the reduction in flange diameter as the cup is drawn and the creation of the hoop compression stress in the flange.

The origin of the test is due to *Sachs*[35], but has also been investigated by *Eksergram*, *Stelles* and *Weiler*, *Brewer* and *Rockwell*, and by *Swift*[25], among others. The test is based on the maximum length of a 1 : 5 taper wedge which may be drawn through a matching die, and on the stress required to pull the wedge through. Test-pieces used by *Sachs*

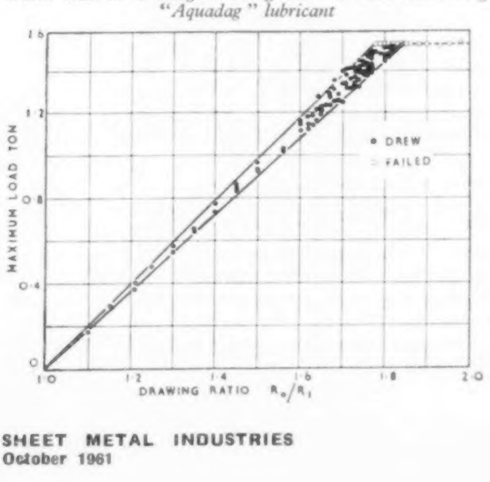
are outlined in Fig. 20, and by *Swift* in Fig. 21, and a die arrangement in Fig. 22. Results from this type of test have tended to be erratic mainly due to the high but variable friction imposed on the edges of the wedge specimen. Thin specimens tend to thicken up more at the taper edges than in the central area. Axiality of loading, case-hardening of dies and adequate lubrication are necessary for consistent results and specimen surface condition, particularly at the edge, is critical. A number of specimens must be prepared to assess the material accurately but this is assisted by the fact that the maximum wedge drawing ratio R_0/R_1 (*see* Fig. 21), correlates reasonably well with maximum drawing load, as shown in Fig. 23. The frictional effects are very difficult to control and the test does not introduce suitable bending and unbending as happens over the die entry profile radius in deep drawing. With these drawbacks, it is not surprising that the wedge-drawing test has declined in popularity and it is probably more complex and troublesome than a full cup-forming test.

Bend Testing

The absence of bending from the wedge-drawing test was criticized on the grounds that bending under tension is an essential part of a deep-drawing operation. Separate bend tests have been used to give a semi-quantitative assessment of this aspect of deep-drawing quality for as long as deep-drawing methods have been used. Unless the specimen is under tension during bending this simple test loses most of what semi-quantitative relationship it has with deep drawability. The test serves to reject material which will not undergo the bending required but a successful bend test result is no guarantee that the material will withstand similar bending in the complex stress field of deep drawing.

As one example of the development of semi-quantitative bend tests the "Flex-tester" instrument[36] is described. The instrument consists of a rigid steel base bent, with a smooth radius, through a 60-deg. angle. A bracket at one end of the base plate clips on to the corner of the sheet to be tested and the instrument is rocked backwards to produce a 60-deg. bend in the corner of the sheet. A dial measures the resistance of the material to the bend and the reading is corrected to take account of differences in sheet thickness. When released, the sheet corner retains a permanent set, the curvature of which can be measured and is said to be a measure of the tendency for the sheet to stretcher-strain marking. It is said to correlate directly with yield-point elongation. This instrument does not claim to measure specific physical properties of the sheet but the readings are accumulated, together with a record of the actual sheet performance, to give grounds for prediction of sheet performance on the press.

Fig. 23.—Relationship between drawing ratio and maximum tensile load in a wedge-drawing test on mild steel using "Aquadag" lubricant



Simple bend tests appropriate to testing of deep drawing and stretch-forming of sheet, are described clearly in B.S.S., 485, 1935.

Lubricant Testing

Before leaving aspects associated with simple cup-drawing tests it is appropriate to mention briefly the rating of lubricants. Work on a small scale has normally used the Swift cup-forming test for this purpose. *Swift*[25], compared lubricants on the basis of the amount by which maximum punch load was reduced in using a given lubricant, when compared with the load required to draw the same cup without lubricant. The reductions in punch load with the better lubricants were of the order of 17½ per cent for mild steel and 30 per cent with aluminium. In this rating, drawing speeds were very low compared with industrial practice so that the results must be interpreted with caution.

Grainger[37], in assessing the efficiency of various lubricants in deep-drawing commercial copper, used a Swift cup-drawing press and recorded the maximum punch load for each lubricant using similar blanks. He plotted these results against blankholder pressure which was varied from 75 to 750 lb. per sq. in. and showed not only the relative merit of each lubricant but also that the relative merit at low blankholder pressure is not the same as at high or medium blankholder pressures.

If accurate assessment of lubricants is required it should be advantageous to plot the punch-load/punch-travel curve for each lubricant using a drawing speed comparable with industrial practice. This requires good instrumentation and an arrangement for high-speed recording such as a ciné record, but it has the advantage of giving an estimate of work done for each test from the area under the load/travel curve. The difference in work done should be a more accurate interpretation of differences in lubrication efficiency than the single figure of maximum load.

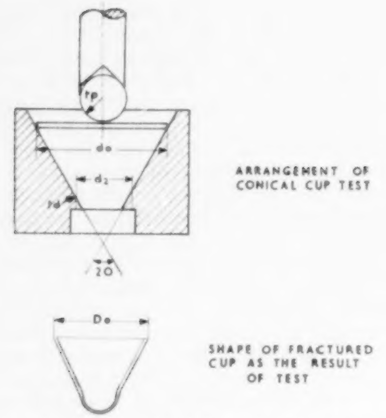


Fig. 24.—Arrangement of tools for a conical cup test and the shape of cup which results from it. [39]

The Conical Cup-forming Test

The cup-forming tests and components of them, described up to this point, have been concerned with the so-called simple, cylindrical cup. A completely different approach was used by Japanese workers in developing a conical cup-forming test. This test was investigated by *Fukui*[38], in 1938, and developed by him and others over the next twenty years, culminating in a full testing procedure in 1958[39]. In the conical cup test, it is possible to draw a sheet without forming wrinkles and without applying any blankholder pressure provided the correct blank diameter is selected with respect only to sheet thickness. The effect of bending and unbending, which is an important factor in a cylindrical cup-forming test, is also less important in the conical cup test. These are convenient simplifications from the point of view of test procedure but they must be taken into account when assessing to what extent the test simulates industrial pressing conditions. Two types of punch have been used, one being hemispherically ended and the other flat ended with a profile radius of approximately 5 to 10 times the thickness of the test blank. The round punch has received more attention. The rating of drawability is obtained from the ratio of the original blank diameter to the average diameter of the rim of the conical cup when fracture occurs. Since the blank diameter is fixed only by the sheet thickness the test is simpler and quicker than the cylindrical cup forming tests.

TABLE IV

Blank thickness, mm.	0.5–0.8	0.8–1.0	1.0–1.2	1.2–1.6
Blank dia., d_0.mm.	38	50	60	80
Conical half-angle of die. θ deg.	60	60	60	60
Die hole dia. d_2. mm.	14.60	19.95	24.40	32.00
Die profile radius, r_d, mm.	3.0	4.0	6.0	8.0
Ball radius, r_p, mm.	6.35	8.73	10.32	13.50

The principle of the test is illustrated in Fig. 24. A circular blank is rested horizontally in the conical die, and drawn with the appropriate punch until the bottom of the cup fractures. The dimensional specifications are given in Table IV :

The die hole diameters specified are such that no ironing of the cup occurs as it enters the die hole. Blanks should be cleaned and then lubricated completely with machine oil of a reproducible quality and the speed of drawing is virtually immaterial. Correlation of the conical cup test with industrial production results has been investigated and will be discussed later.

The simulative test procedures have been outlined in this account in sufficient variety and detail to allow discussion of their relation with each other, with non-simulative test results and with results from works practice. Other tests exist but they are mainly modifications of those described and, as such, do not warrant special attention.

Rating the Severity of Pressings

Before a suitable test can be selected for the purpose of examining material destined for a given pressing, it is necessary to know as much as possible about the mode and severity of deformation of the sheet in forming the component. An experienced press-shop supervisor can deduce a great deal about both the mode and severity of deformation from an engineers' drawing but, at best, this will be a qualitative interpretation. The interpretation is easier, though still qualitative, if use is made of models of the component. A scaled-down version of the component may be produced in a small press in order mainly to develop satisfactory tool arrangements. These small-scale pressings, if they are reasonably accurate replicas, are also useful in examining flow patterns. However, it is very difficult, if not impossible, accurately to scale down the thickness of sheet used in producing these small replicas and quantitative measurement of strains on them is likely to be misleading. The most informative tests are associated with full-scale trials of the job on the press but this method is expensive in material. The part may be tried out with various qualities of sheet in order to give a broad classification but except for borderline cases this method gives little or no more information than an experienced judgment of the drawing or an example of the part. When a reasonably satisfactory tool arrangement and material have been selected and the job is in production, the reject percentage becomes a very powerful means of assessing material. It follows, therefore, that a

(*Continued in page* 741)

Quantitative Assessment of Deep-drawing and Stretch-forming Qualities

(*Continued from page* 740)

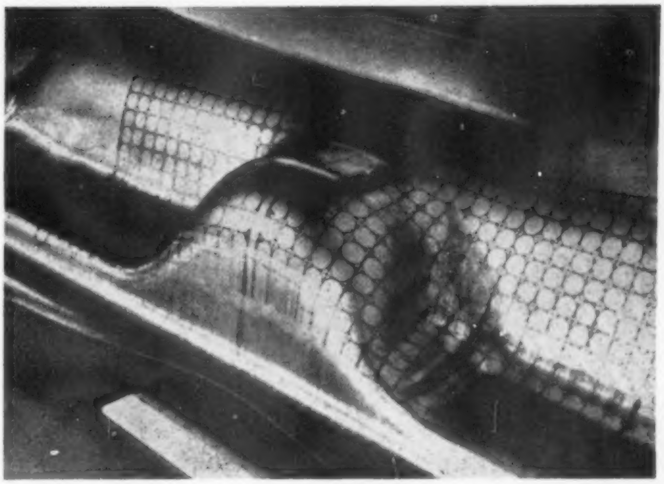


Fig. 25.—A typical deformed grid for rating local strain (Nelson[3])

supply of carefully chosen material of consistent properties can be used to rate pressing severity by the reject percentage. The most economical method of rating pressing severity in a semi-quantitative fashion is by printing a grid on the blank and then to measure the local strains after forming. The severity rating is then normally based on the maximum strains observed. The size of the grid is chosen to suit the general size and intricacy of the pressing and it has been suggested that the most suitable pattern is a series of squares including tangential circles rather than simple squares alone[40]. An example of a typical deformed grid is shown in Fig. 25, from a paper by *Nelson*[3]. From this type of investigation it is possible to be very selective in sampling sheets for other tests. If samples are limited, for instance, they may be taken from areas of the sheet where maximum deformation is expected during pressing. This is particularly important when using sheet material with somewhat heterogeneous properties such as rimming steel sheet. Having matched the sample position with the pressing it is also possible to be selective over the particular test value required to give a reasonable estimation of behaviour at that position. Referring to the simple tensile test, for example, uniform elongation values are likely to be more significant in areas where stretch-forming is reasonably uniform and extensive, whereas overall elongation may be a better criterion in small severe stretch-formed pressings or in regions of highly localized strain in large pressings.

(*To be continued*)

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BISRA RESEARCH SECTION RENAMED

Steady Growth in Activities

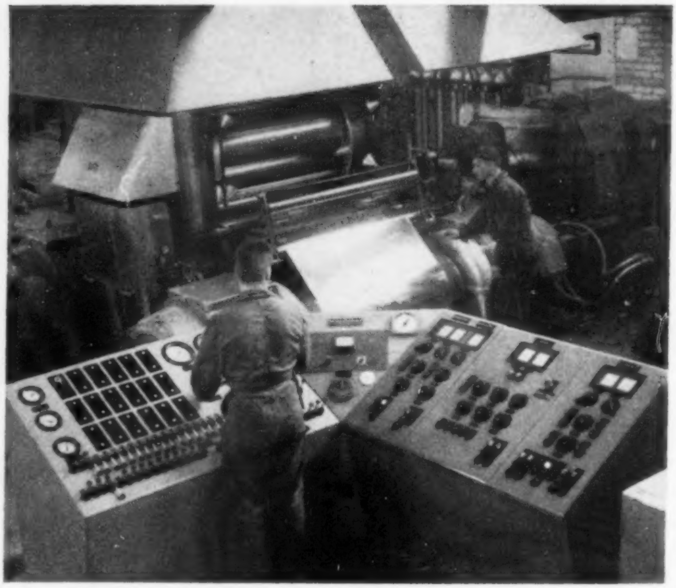
IN recognition of the steady growth in the scope of its activities over recent years, the Computer Applications Section of BISRA's Operational Research Department has now been re-named the Systems Evaluation Section.

The duties of the new section, which will be headed by Mr. D. H. Kelley, B.Sc., will be to carry out operational research investigations into the automation of large-scale systems.

The immediate programme will be to study the automatic production planning and scheduling of various kinds of steelworks, and to investigate the information requirements of steelworks management.

The services to Members which were previously supplied by the Computer Applications Section and which included operation of the Association's Pegasus computer, advice on the uses of digital computers in steelworks offices and the training of Pegasus programmers will be continued unchanged.

New Swedish Aluminium-Foil Mill in Production



In the 4-high mill at Skultunaverken the thickness of the foil is decreased from 0.7 mm to 0.02 mm. From the table in the foreground pressure of rolling, cooling liquid, rolling speed, etc., is controlled. Each coil contains 2,000 kg. of aluminium with a width of 1,200 mm. If all this was rolled up to household foil it would be 25,000 rolls

WITH a present output of 1,100 tons per annum, corresponding to two-thirds of the Swedish consumption of this product, a new aluminium foil mill has recently been placed in production at Skultuna, Sweden, by AB Svenska Metallverken, the country's largest producers of non-ferrous metal products. With the opening of the new plant, all aluminium foil production has now been transferred to Skultuna from Finspång.

The raw material will still come from the Finspång plant in rolls of 2,000 kg., the bands of which are 0.7 mm. thick and 1.25 m. wide. These are then rolled down to $\frac{1}{80}$th of the original thickness, or a thickness of 0.009 mm., the usual size for packing material. Different thicknesses will, however, be produced according to the purposes for which the end product is required. Facilities are also available at Skultuna for embossing patterns, trade marks, etc., into the foil, as well as for finishing the various colour prints.

Continuous control is exercised over the whole production line, density, strength, thickness, etc., being continuously tested during rolling. The surface of the foil is particularly carefully scrutinized, as it must have a special finish for the continued treatment, *e.g.* lacquering, colour printing, etc. Control is carried out from the laboratory which takes a sample from each machine every other hour. The printing and colouring is done in rotary machines and the colours, in most cases, are quickly-drying plain lacquers used to protect the foil from water or chemical attack and to make the foil firmer. For certain higher-class wrappings the foil is then often further lacquered with a very thin colourless lac film which gives good protection against scratches.

Since AB Svenska Metallverken are the only manufacturers of aluminium foil in Sweden, the Skultuna works sells about 90 per cent of its output to the packaging industry while the remainder, about one million rolls, is marketed as household foil.

The new factory has at present a maximum productive capacity of 1,500 tons, with possibilities for further expansion.

Steelmen to visit U.S.S.R.

THREE R.T.B. managers from Spencer Works and Ebbw Vale are to visit Russian steelworks. Permission for the visit which will last for two to three weeks has been received; although it is hoped that the tour will take place before the end of the autumn, no further details of dates or itinerary are yet available. The R.T.B. trio is: Mr. A. J. Burgess (Ironmaking Manager, Spencer Works); Mr. W. R. Harrison (Blastfurnace Manager, Spencer Works); and Mr. C. Penry (Coke and Iron Manager, Ebbw Vale).

A Survey of

METHODS USED FOR THE INSPECTION OF SHEET METAL

By R. F. LUMB*, B.Sc. (Hons.)

INTRODUCTION

STEEL ingots are subject to centrally situated defects originating from impurity segregation, the evolution of gases and the contraction of the melt during solidification. On rolling to sheet, though small cavities comprising the secondary pipe usually weld up, other defects persist and give rise to laminar discontinuities within the sheet thickness. These laminations are elongated in the direction of rolling. Primary pipe, the large contraction cavity at the top of an ingot, is particularly deleterious as its heavily oxidized surface will never weld up during rolling.

In normal practice a fixed portion of the ingot, corresponding to the pipe, is cropped. Severe laminations result if this discard is inadequate, a typical example in silicon steel being shown in Fig. 1.

Laminations may give trouble when the sheet is subsequently fabricated by causing sheared and punched edges to split open, the formation of blisters and the rupture of one or both surfaces on pressing, and poor-quality welds due to blistering of the heat-affected zone and the effect of oxide in the weld deposit.

The construction of the magnet pole-pieces for the NIMROD proton synchrotron involves the use of several hundred thousand silicon-steel sheets of two thicknesses, 0.020 in. and 0.030 in. The sheets are bonded together by epoxy resin and are subject to considerable shear stresses resulting from magnetic forces in the plane of the sheets. Pole-piece design was based on the assumption that the limiting resistance to the shear stresses would be the resin bond. However, it may be that a severely laminated sheet could fail through the lamination at lower stress. In view of this, inspection of the sheets was considered necessary.

In this paper the available non-destructive inspection techniques are reviewed. A number of hot- and cold-rolled sheets have been inspected and the observations correlated with a subsequent destructive examination. Factors affecting the choice of technique are discussed.

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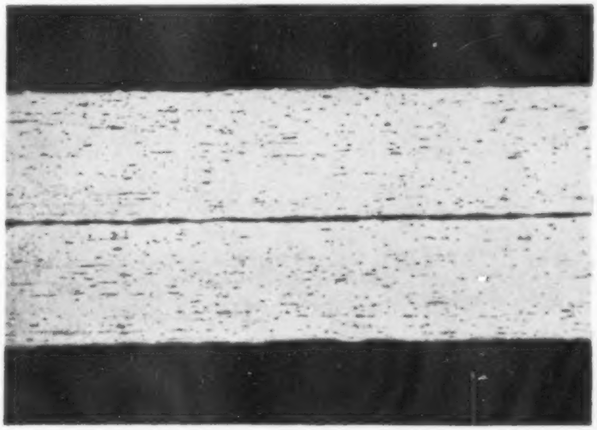


Fig. 1.—Typical laminations in cold rolled sheet, unetched (× 50)

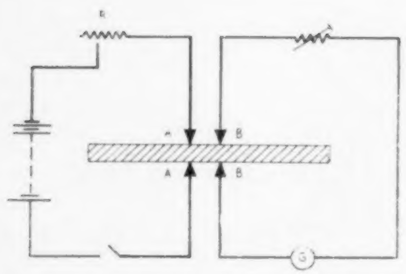


Fig. 2.—Circuit diagram for an electrical resistance test

ELECTRICAL-RESISTANCE TECHNIQUE

1. *Method*

Laminations, having high electrical resistance, will obstruct the passage of an electric current flowing in a direction perpendicular to the sheet. The current is diverted to circumvent laminations, and the electrical potential across the sheet rises, due to the increased current-path length and the reduced current cross-section of the defective zone. In the circuit diagram (Fig. 2), a continuous direct current is fed across the plate through the contacts AA *via* a ballast resistor R, which controls the current and swamps changes in contact and sheet resistance. The potential drop across the sheet is measured between the adjacent contacts BB, which are electrically insulated from AA. Work at B.I.S.R.A.[1] has shown that for optimum sensitivity the contact spacing AB should be of the order of the sheet thickness. Ideally, to eliminate the effect of the contact resistance associated with the probes BB, the potential drop should be measured by a null-current potentiometer circuit, but a high-internal-resistance millivoltmeter was found to be adequate.

Experimental Investigation

The sheets were tested in a simple device (Fig. 3) in which the silver-steel contacts, insulated from each other by a strip of Paxolin, were mounted in Tufnol blocks attached to the ends of a rigid angle-iron fork. In the cold-rolled sheets the regions of lamination were clearly indicated by the potential difference across the sheet increasing from less than ten microvolts to one or two millivolts. Laminations covering the full length and one third of the width of the 4-ft. by 7-in. sheets were observed. The smallest laminations that could be detected were about ½ in. square.

Some sheets were also examined using an equipment designed by B.I.S.R.A. and manufactured and marketed by the Ultrasonoscope Company. The contacts, insulated from each other by strips of oiled silk, were mounted at one end of a pair of 24 in. long Duralumin tongs pivoted about 3 in. from the other end. The current supplied to the contacts was rectified a.c. and the millivoltmeter indicating potential drop was conveniently mounted on the tongs. Initially, operation of the equipment was erratic as the contacts became offset and nonperpendicular to the sheet, due to the length of the tongs from the pivot to the contacts. By incorporating a guiding arrangement towards the contact end of the tongs satisfactory performance was obtained.

A high potential was indicated over the whole of the hot-rolled sheets, confirming previous work by Smith *et. al.*[1] who attributed the observations to a thin, electrically-resistant, oxide layer remaining after pickling. Isolated local regions of higher potential were observed which, as no laminations were revealed on sectioning, probably resulted from areas of thicker oxide skin.

If two parts of a cold-rolled sheet are folded together across the rolling direction and then straightened, blisters form along the crease whenever it traverses a laminated region. Such destructive tests confirmed the position and extent of defects indicated by the electrical-resistance examinations. Also tests in a few of the regions in which no defects were indicated by the non-destructive examination confirmed that those regions were "sound". The presence of laminations in the hot-rolled sheets could only be confirmed by sectioning, as the sheets were too brittle to bend. It has been

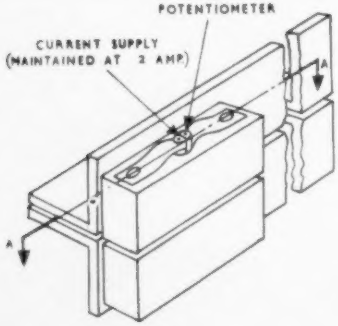
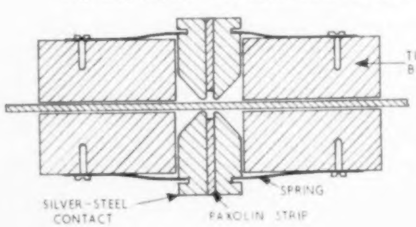


Fig. 3(a) (left).—Equipment for electrical-resistance method of inspection

Fig. 3(b) (right).—Enlarged section at AA



previously mentioned that no laminations were observed in the sections taken.

ULTRASONIC TECHNIQUES

A. Transmission Technique

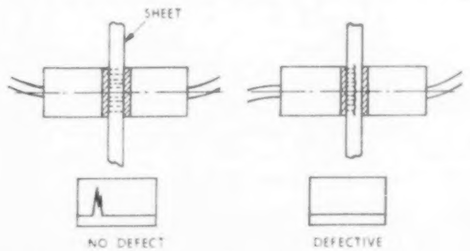
Method

In the ultrasonic examination of plate by the pulse-echo technique, compression waves are propagated through the plate thickness, and, in the absence of laminations, a sequence of uniformly-spaced multiple echoes from the back surface is obtained. The method is not suitable for sheet as the duration of the echo at the front surface is not short enough to allow resolution of that from the back surface. In the transmission technique illustrated in Fig. 4, defects are detected because of their ability to interrupt the passage of ultrasonic waves through the sheet. As laminar-type defects are ideally oriented for this, the technique is suitable for sheet inspection.(2) Both contact and immersion scanning arrangements are feasible.

Fig. 4 shows a system which requires one transmitting and one receiving probe suitably positioned on opposite faces of the sheet, a film of thin machine oil being interposed between the probe and the sheet.

Two difficulties arise when large areas are scanned namely, maintaining constant coupling, and avoiding excessive probe wear. Immersion coupling, in which the probe is separated from the sheet by an appreciable liquid gap, avoids these difficulties and is more adaptable to mechanized inspection. Fig. 5a illustrates an arrangement using separate transmitting and receiving probes. The probes, mounted on the same axis, are moved relative to the sheet, which must be normal to the ultrasonic beam at its point of entry. An alternative arrangement using one transmitter-receiver probe is illustrated in Fig. 5b, the transmitted energy being reflected back to the probe by a suitable mirror normal to the probe axis. The trace obtained on the C.R.O. shows echoes from the surface of the sheet S (repeated at S_R) and from the mirror M. Should a defect be present, no energy reaches the mirror,

Fig. 4.—Ultrasonic transmission testing equipment, contact method, requiring one transmitting and one receiving probe



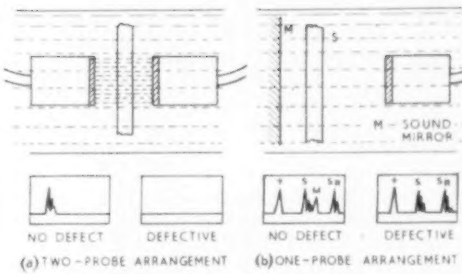


Fig. 5.—Typical immersion method of ultrasonic transmission testing

and echo M will not occur. With thicker sheets, especially if high-frequency probes are used, rapidly decaying multiple echoes resulting from reflections at the sheet surface remote from the probe occur after S. The distances between the probe, sheet and mirror must be so adjusted that the echoes S, M, and their multiple and repeated echoes, do not interfere with one another. This condition is easily satisfied for sheet.

Automatic recording of defects is easily achieved in both immersion testing arrangements, as instruments are available which will monitor a particular echo in such a way that when it falls below a predetermined amplitude a relay is triggered. The relay can then operate a pen recorder, or if preferred, a warning light or bell.

Three scanning systems are possible, the most suitable being determined by engineering considerations:—the sheet can be held stationary and the ultrasonic beam moved over it, or the probe system can be fixed and the sheet moved relative to it, or some combination of the two can be used. It is envisaged that the latter arrangement would be particularly suited to continuous or semi-continuous inspection, as in the example shown in Fig. 5b, coverage across the sheet could be obtained by vertical movement of the probe while feeding the sheet past the probe would provide coverage along the sheet. By this means the ultrasonic beam would follow a sinusoidal path over the sheet surface, the "pitch" being determined by the relative rates of movement.

As thin sheet tends to flex in its own plane, the region under inspection must be supported to keep it flat and normal to the ultrasonic beam. The scanning system can be arranged to accommodate guiding devices which maintain the sheet vertical (as illustrated in Fig. 5) or horizontal.

The ability of a discontinuity in metal to interrupt the propagation of ultrasonic waves of a particular frequency is a function of its nature and thickness. For example, if an ultrasonic wave were propagated at 1 mc. per sec. frequency in steel, a crack 10^{-7} in. thick would reflect 90 per cent. of the energy

incident on it, whereas a typical silicate inclusion 10^{-2} in. thick would only reflect 20 per cent. Serabian and Moriarty [3] established that, as the thickness of laminar defects is typically 10^{-4} to 10^{-3} in. ultrasonic detection is only possible if the defects contain micro-separations or cracks. These discontinuities, of the order of 3×10^{-7} to 10^{-6} in. thickness, occur either within the lamination or, more usually, at the lamination-steel interface. Electron microscope observations have shown that the micro-separations result from small amounts of deformation at a sufficiently low temperature for the laminar inclusion to be harder than the steel. This condition arises during cold working. Generally laminar defects are also detected ultrasonically in hot worked steel thus suggesting that the steel only becomes the harder towards the top of the hot working temperature range. However, absence of micro-separation is a potential limitation to be taken into account during inspection of hot rolled sheet.

B. Lamb Wave Technique

Method

Lamb waves [4] (which are alternatively known as plate waves) are established by the same mechanism as shear and surface waves. If a beam of compression waves is directed at a high angle of incidence to the surface of a plate which is thick compared with the ultrasonic wavelength, the beam is retracted as shear wave, or, if the angle of refraction approaches 90 deg. as a surface wave. The plate vibrates only in the region of the ultrasonic beam. When the sheet is sufficiently thin the vibration extends to the complete thickness and Lamb waves are formed. Symmetrical Lamb waves cause the sheet to pulsate so that at any point it regularly expands and contracts; asymmetrical Lamb waves create a rippling motion. Both types are equally suitable for inspection.

Lamb waves are generated when the compression wave is incident at particular angles which depend on the wave frequency and the nature and thickness of the sheet. The most suitable angle is determined experimentally by scanning the edge of a sheet with a variable angle probe, and observing the echo reflected from it. With thinner-gauge sheet the angle appears to be less critical and a surface wave probe suffices.

Laminations act as regions where the effective sheet thickness is reduced, and as this affects the mode of vibration a reflection occurs. In the usual scanning procedure, the probe is placed at one side of the sheet and the beam directed to the opposite side, energy being reflected back to the probe from the sheet edge. Coverage of the sheet is obtained by moving the probe down the length of the side.

The use of Lamb waves simplifies the problem of scanning the large areas of sheet, as considerable coverage is achieved by moving the probe parallel to the long edge of the sheet. As laminations are much elongated in the direction of rolling, scanning across the rolling direction ensures maximum probability of detection.

Experimental Investigations

The sheets previously inspected by the electrical-resistance technique were examined by the method illustrated in Fig. 5b, the sheets being held rigid and the probe scanned over them. Ultrasonically indicated defective regions showed excellent correlation with the electrical resistance and subsequent destructive examinations. Flaws less than ¼ in. square could be detected, delineation being comparable to that obtaining in the electrical-resistance method. Again no defects were observed in the hot-rolled sheets available.

Lamb wave tests on some of the sheets defined the laminations with a similar accuracy to the transmission method. However, tests on some other cold-rolled, and all of the hot-rolled sheets were not successful because the beam was so severely attenuated that it was not possible to obtain an echo from the opposite edge of the sheet, Fig. 6*a* being a typical illustration from a sample of cold-rolled and annealed sheet. Sections indicated the presence of scattered fine inclusions (Fig. 7*a*) and, on etching, course grains (Fig. 7*b*). Both these metallographic features contribute to ultrasonic transmission. After a normalizing treatment which refined the grains by a factor of about three, the satisfactory trace shown in Fig. 6*b* was obtained, Fig. 6*c* being the trace at a region of lamination. The reduced attenuation shown by these latter two traces suggests that grain-size was mainly responsible for the attenuation.

MAGNETIC METHODS

Method

On approaching magnetic saturation, any local increase in flux density is accompanied by a considerably larger increase in the local magnetising force. In defective regions the thickness of the steel is reduced as space is taken up by the lamination, and the resultant increase in flux density can then be observed by some form of magnetic scanning close to the sheet surface.[5]

Experimental Investigations

Scanning was achieved by the use of captive magnetic fluid which accumulated over the more highly magnetized (and hence defective) areas. Though correlation with a destructive examination was reasonable, scanning was slow and delineation of defective areas less pronounced than in the techniques previously described.

ASSESSMENT

Electrical-resistance Technique

Cold-rolled Sheets

This method is simple and reliable for detecting

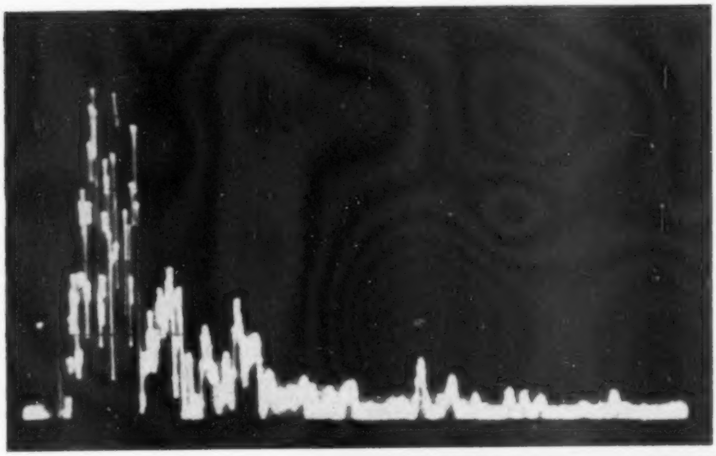
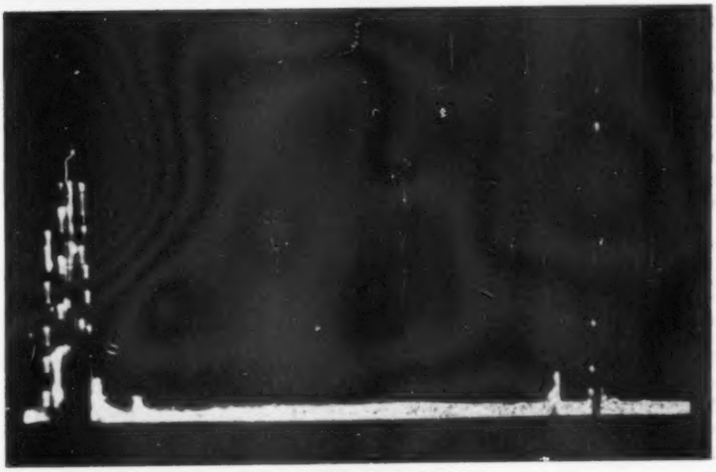


Fig. 6(a).—Trace from sheet in cold-rolled and annealed condition

Fig. 6(b).—Trace from sheet in cold-rolled and annealed condition after normalizing, showing reflection from edge of sheet



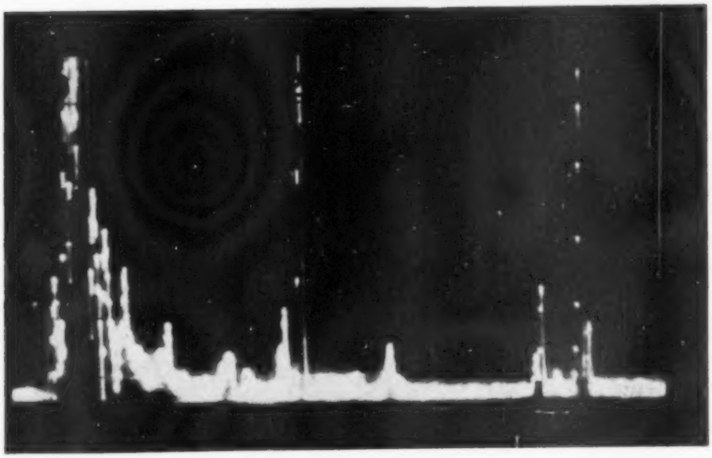


Fig. 6(c).—Trace from part of normalized sheet in which there is a lamination approximately mid-way between probe and sheet edge

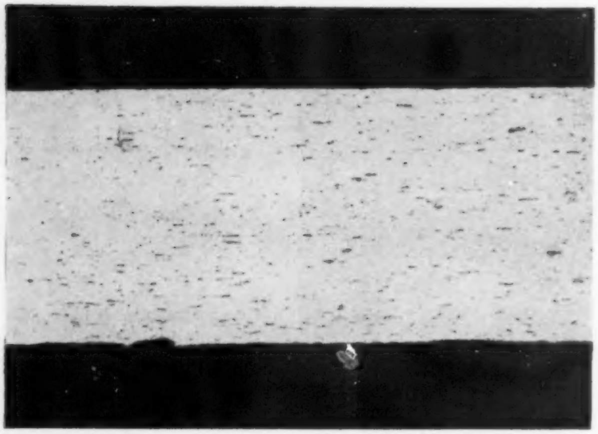


Fig. 7(a).—Section taken from cold-rolled and annealed sheet, unetched (× 50)

laminations greater than ½ in. wide, and gives good delination between defective and defect free zones. Although a prototype equipment incorporating continuous automatic scanning and recording has been operated with moderate success[6] the method seems less adaptable to mechanization than ultrasonics. The most useful application of the method is the inspection of small and medium batches of sheet, particularly if the more expensive ultrasonic equipment is not available.

Hot-rolled Sheets

The possibility of spurious observations resulting from a thin oxide skin remaining after pickling precludes the use of the method for hot-rolled sheets. In addition, Smith *et. al.*[1] found that laminations observed visually at the sheet edges were not always detected, even after oxide skin had been removed by grinding the sheet surface with emery paper. This was attributed to the oxide of the lamination becoming relatively plastic at high temperatures so that on rolling small tongues of steel could bridge the laminations and provide electrical conduction.

Ultrasonic Transmission Technique

Cold-rolled Sheets

Defect detection is reliable in all types of sheet whether the contact or the immersion coupling arrangement is used.

Contact Scanning. As probe manipulation can be carried out manually the method is convenient for the inspection of occasional small batches of sheet. Examination of large quantities of sheet by this method is tedious.

Immersion Scanning. When combined with automatic scanning and recording, the method is the most suitable of those at present available for the inspection of very large quantities of sheet.

Hot-rolled Sheet. Subject to the possible limita-

(*Continued in page* 760)

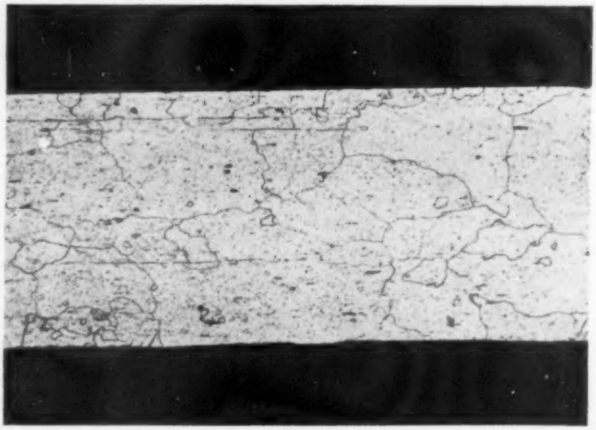


Fig. 7(b).—Section from cold-rolled and annealed sheet, etched in 2 per cent nital (× 50)

THE EFFECT OF ELECTROPLATING PROCESSES ON THE FATIGUE STRENGTH AND EMBRITTLEMENT OF THE SUBSTRATE*

By C. WILLIAMS†

*(*This article is based on a lecture given at Joint Meetings of the Institute of Metal Finishing and the Institute of Metals. A more complete account of this topic, together with a bibliography, is given in* "*Metallurgical Reviews*," 1960, **5**, (18), *p.* 165).

THE engineering applications of electrodeposition are very largely confined to the treatment of steel components and probably for this reason there are relatively few references in the literature to the effects of plating on the mechanical properties of non-ferrous materials. This article deals therefore with steel as the substrate.

For engineering as distinct from corrosion-resistant applications, it is essential that, in addition to being firmly adherent to the basis metal, the coating itself should possess good mechanical properties. With suitable control of plating conditions most electrodeposited metals can be produced with mechanical properties equal, and sometimes superior to the corresponding metallurgical product, and the strength of the component under static loading conditions is not usually adversely affected by the electrodeposit, unless the nature of the substrate metal is such that it is subject to embrittlement by hydrogen released in the pickling and plating processes. Under conditions of alternating stresses however, the electrodeposits commonly used for building-up or for hard surfacing, such as nickel and chromium, usually produce a marked reduction in the fatigue strength of steel; for example under unfavourable conditions the fatigue strength of a strong steel can be reduced as much as 80 per cent by chromium plating. Nevertheless, in spite of the large loss in fatigue strength frequently reported in the literature as arising from electroplating, very few service failures are directly attributed to electroplating. The risk is present however and, unless suitable precautions are taken, will increase with the prevailing tendency to use steels of ever-increasing tensile strength, *e.g.* in aircraft components.

Fatigue

Almost invariably, investigators have used specially-prepared test-pieces rather than actual components for determining the effect of electrodeposition on fatigue strength, and the results so obtained may not therefore be directly applicable to service conditions. With the rotating bend type of test most commonly used, the mean stress (that is, the superimposed steady stress) is zero and these conditions do not always apply in practice.

Test-pieces are usually made by first turning roughly to size and finished by grinding or polishing, and they are not often stress-relieved immediately before testing. Turning introduces compressive internal stress extending for considerable depths below the surface, while grinding often produces high tensile stresses near the surface. Such stresses, coupled with the indeterminate thickness of metal removed during pickling or etching before plating, can seriously affect the validity of the test results. Some investigators have sought to eliminate this variable by electropolishing the steel test-piece to a sufficient depth before electroplating. With some steels thermal stress-relief before plating would be an alternative possibility. However, in spite of the limitations of laboratory tests, they have provided much valuable information on the fatigue properties of plated steel, particularly for chromium and nickel deposits, and have established methods of minimizing or even eliminating the loss in fatigue strength.

1. Chromium

Electrodeposited chromium though hard, has negligible ductility and, normally contains internal cracks and cannot therefore be relied upon to contribute to the overall strength of a plated component. The inherent fatigue strength is relatively low, however, and is usually about 22 tons per sq. in. and high-strength steels usually suffer a serious loss in fatigue strength on chromium plating (Fig. 1), and there is a further loss in fatigue strength on heat-treatment at *ca.* 200° C. Fig. 1 also illustrates that whereas in the "as plated" condition the fatigue strength is independent of thickness in

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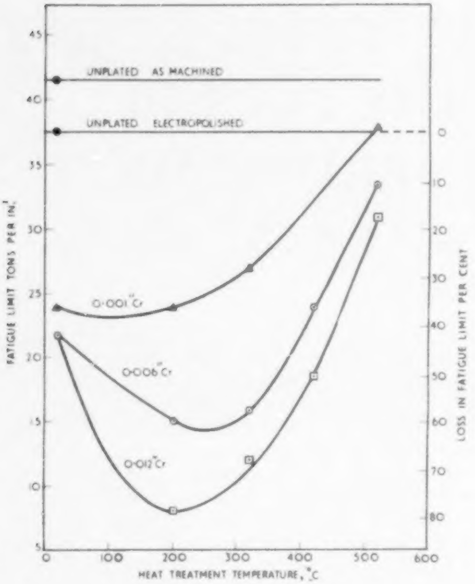
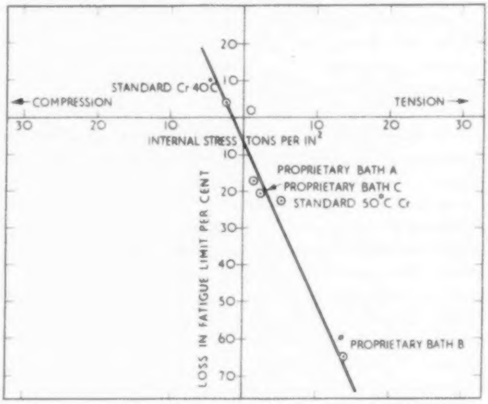


the range 0.001 to 0.012 in. Cr, after baking at *ca.* 200° C. to remove hydrogen from the steel the loss in fatigue strength increased with the thickness of chromium above 0.001 in.

Electrodeposited chromium normally contains tensile internal stress, the magnitude depending on the conditions of deposition. Since fatigue failure is essentially a tensile-stress phenomenon the loss in fatigue strength on plating has been associated with the internal tensile stress in the deposit by several investigators, and Logan postulated that, as the characteristic cracking (during plating) of chromium indicated some relief of residual stresses, specimens that have the largest number of cracks per unit area would be expected to have the lowest residual stresses. By inference this would suggest that the density of the crack pattern will be reflected in the extent to which the fatigue strength is depressed by chromium plating, and this was found to be so by Stareck *et al.* (Fig. 2). As the number of plating cracks increased, the internal stress decreased and the fatigue strength increased.

Concurrent investigations at the Armament Research and Development Establishment, Fort Halstead, also showed that the percentage change in fatigue strength on chromium plating was a linear function of the residual stress in the chromium deposit. This was done in two ways: (i) by using different types of chromium plating baths and (ii) by post-plating heat-treatment of standard chromium from the conventional bath. (Figs. 3 and 4).



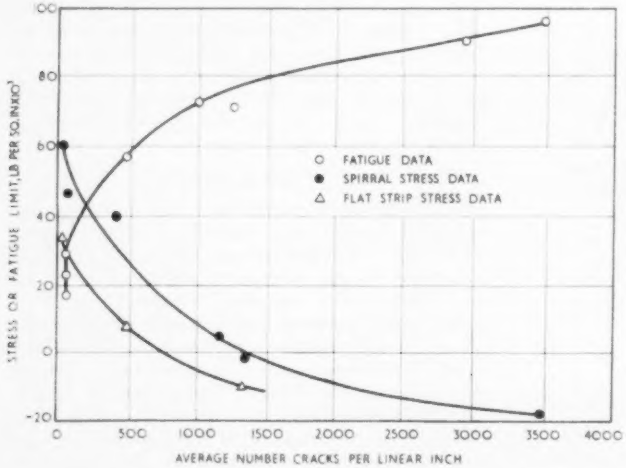


Fig. 1 (above, left).—Effect of heat-treatment on the fatigue limit of chromium-plated steel of 80 tons per sq. in. TS. (Williams and Hammond)

(Courtesy Institute of Metal Finishing)

Fig. 2 (left).—Interdependence of fatigue limit of chromium-plated steel with internal stress and crack density in the chromium deposit. (Stareck et al)

(Courtesy American Electroplaters' Society)

Fig. 3 (above).—Linear relationship between the percentage change in fatigue strength of chromium-plated steel and the internal stress of various types of chromium deposit for "as-plated" (i.e. unbaked) deposits. (Williams and Hammond)

(Courtesy Institute of Metal Finishing)

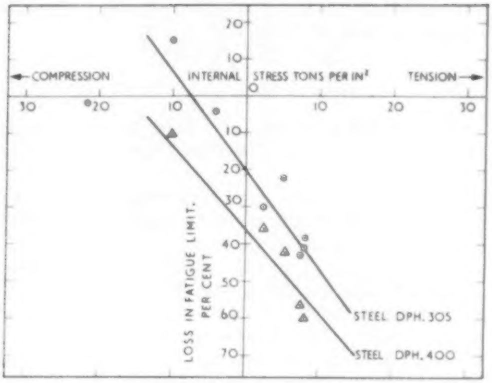


Fig. 4.—Linear relationship between the percentage change in fatigue strength of chromium-plated steel and the residual internal stress in standard chromium after baking. (Williams and Hammond)

(Courtesy Institute of Metal Finishing)

Until comparatively recently baking after chromium plating at 150 to 200° C. was commonly specified for relieving hydrogen embrittlement of the steel arising from the plating processes, but several investigators, *e.g.* Wiegand and Scheinost, and Logan have shown that this treatment further reduces the fatigue strength. This feature is illustrated in Figs. 1 and 5 which are based on tests carried out in A.R.D.E. Fig. 5 also shows that if heat treatment can be carried out at sufficiently high temperature the fatigue strength can be restored to that of the unplated steel.

The improvement in fatigue strength after high-temperature baking is believed to be due to compressive stresses which arise from, first, stress relief at temperature, followed by differential contraction of the steel and the chromium on cooling (coefficient of expansion of chromium is only approximately half that of steel).

It has been generally appreciated for many years that the loss in fatigue strength on chromium plating is more serious with the stronger steels, and Fig. 6 shows the linear relationship between the percentage change in fatigue strength on chromium plating and the fatigue strength of the steel itself. A simple equation can be given for this line (which is for standard chromium deposits in the "as plated" condition) and it is thus possible to calculate the approximate change in fatigue strength likely to result from chromium plating, from a knowledge of the fatigue strength of the steel. Thus,

$$L = 50 - 2F_s - 3S$$

where L = percentage change in fatigue limit,

F_s = fatigue limit of the steel (tons per sq. in.),

S = internal stress in the chromium deposit (tons per sq. in.)

Alternatively, the tensile strength or hardness of

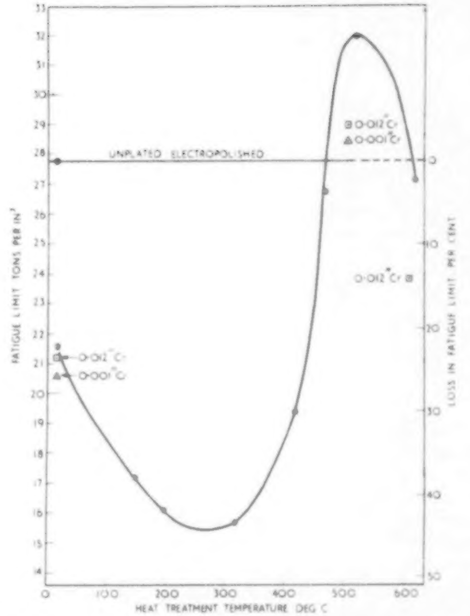
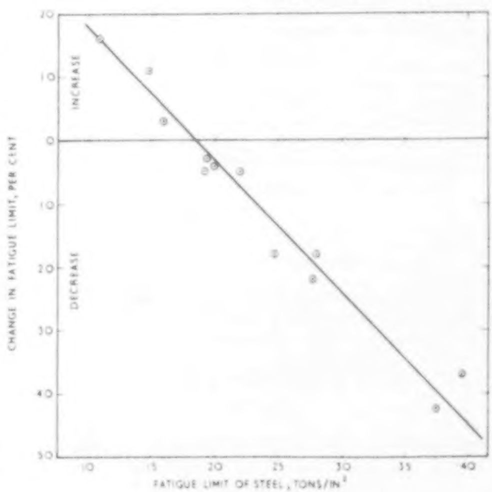


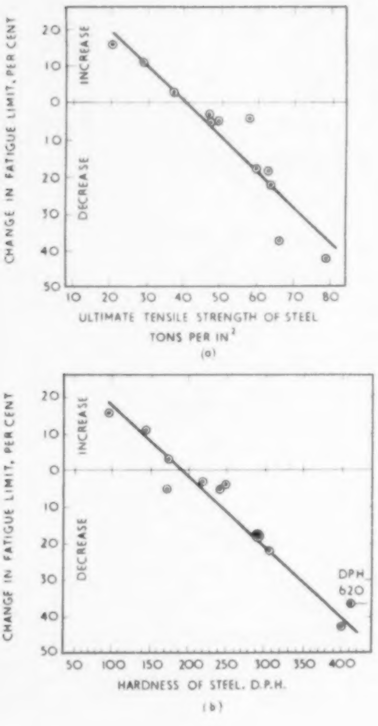
Fig. 5.—Effect of heat-treatment on the fatigue limit of a steel of 60 tons per sq. in. TS, plated with 0.006 in. of chromium; see also Fig. 1 for results of similar tests on a steel of 80 tons per sq. in. TS. (Williams and Hammond)

(Courtesy Institute of Metal Finishing)

Fig. 6.—Linear relationship between the change in fatigue limit after chromium plating and the fatigue strength of the steel substrate. (Thickness of chromium 0.006 in.; internal stress 4 tons per sq. in. tensile). (Williams and Hammond)

(Courtesy Institute of Metal Finishing)





the steel may be used, as shown in Fig. 7 or the equations for these lines, *viz*:

$$L = 50 - T - 3S$$

$$\text{or } L = 50 - \frac{H}{5} - 3S$$

where L and S are as before, T is the tensile strength (tons per sq. in.) and H is the hardness (HV) of the steel base.

The serious loss in fatigue strength that occurs with the stronger steels can be reduced by baking after plating at a temperature exceeding 440° C. (as shown in Figs. 1 and 5). There are two practical limitations to the employment of high temperature baking however: (i) the chromium becomes progressively softened with increased baking temperature and (ii) the temperature must not exceed the tempering temperature of the steel. There is no way of avoiding the first limitation. However, the residual hardness of the chromium (*ca.* 600 HV) would be high enough for many purposes. The second limitation applies only to strong steels *e.g.* those with tensile strengths exceeding 80 tons per sq. in. and will become less important when new types of high strength steels with high tempering temperatures come into use. However, for steels that cannot be given this high temperature heat treatment, shot peening may be used as an alternative method of maintaining the fatigue strength on chromium plating.

Shot-peening of the steel before plating was shown by Almen to eliminate the loss in fatigue strength that normally occurs when *low*-strength steels are either nickel or chromium plated. (Fig. 8).

Fig. 7 (above).—Linear relationship between the change in fatigue limit on chromium plating and (a) *the strength and* (b) *the hardness of the steel substrate (Thickness of chromium* 0.006 *in.; internal stress* 4 *tons per sq. in. tensile*). (Williams and Hammond)

(*Courtesy Institute of Metal Finishing*

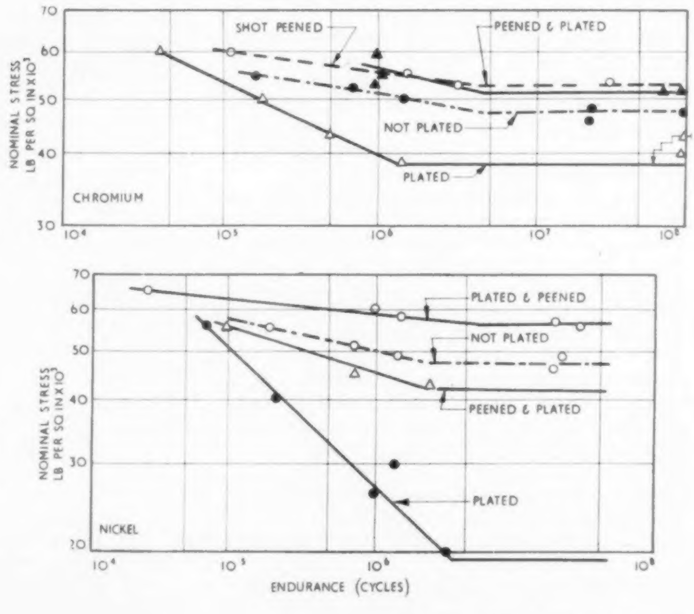


Fig. 8 (right).—Effect of shot-peening on the fatigue strength of (a) *chromium and* (b) *nickel-plated steel* (Almen)

(*Courtesy "Product Engineering"*)

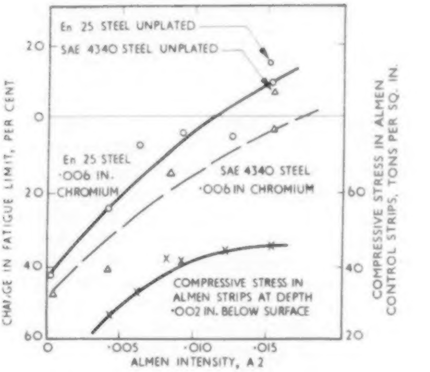


Fig. 9.—Effect of shot-peening before chromium plating on the fatigue limit of En 25 steel (80 *tons per sq. in. TS*) *and S.A.E.* 4340 *steel* (100 *tons per sq. in. TS*). *The lowest curve shows the calculated internal compressive stress* 0.002 *in. below the surface at various peening intensities.* (Williams and Hammond)

(*Courtesy American Electroplaters' Society*)

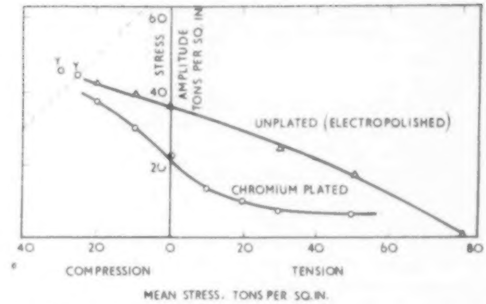


Fig. 10.—*Effect of non-fluctuating,* i.e. *mean, stress on the fatigue strength of unplated and chromium-plated En* 25 *steel heat-treated to* 80 *tons per sq. in. TS.* (Williams and Hammond)

(*Courtesy American Electroplaters' Society*)

Later Cohen, using high-strength steels (100 and 125 tons per sq. in. TS) showed that shot-peening before chromium plating virtually maintained the fatigue strength of the steel both in the "as plated" and "baked at 190° C." (to remove hydrogen embrittlement) conditions. Tests carried out in A.R.D.E. confirmed this important result, using 80 and 100 tons per sq. in. TS steels (Fig. 9 and Table I). These tests showed a progressive increase in fatigue strength with increasing intensity of peening, and that a minimum intensity of peening of 0.012 to 0.015 A2 was necessary to restore the fatigue strength to that of the unplated steel, and thus to eliminate the loss in fatigue strength of about 40 to 50 per cent which would occur if peening was omitted.

Table I also confirms that, in contrast to the effect on unpeened steels, baking at 200° C. to eliminate hydrogen embrittlement has no effect on the fatigue strength of the peened and chromium plated steel.

Peening introduces high compressive stresses near the surface of the steel (Fig. 9, lowest curve) and the improvement in fatigue strength obtained by peening before plating is believed to be due mainly to these stresses. The beneficial effect of compressive stresses has been confirmed by carrying out push-pull fatigue tests on *unpeened* but plated specimens and applying varying amounts of steady non-fluctuating stresses by the fatigue testing machine itself. The fatigue strength with various steady *i.e.* mean stresses, were determined and the results are given in Fig. 10. The very substantial improvement in fatigue strength with increasing compressive mean stress is linear, and the diagram also shows the extremely harmful effect of tensile mean stresses on chromium plated steel.

Peening introduces a roughening of the surface which would render it unsuitable for running parts. It has been established however that a peened test-piece can be ground smooth either before or after chromium plating without loss of fatigue strength provided that no more metal is removed from the surface than is required to eliminate the peening texture (*ca.* 0.001 to 0.0015 in.).

2. Nickel

Electrodeposited nickel is softer and more ductile than chromium and, by selecting the appropriate

TABLE I.—*Effect of Baking on the Fatigue Strength of Peened and Plated Steels* (Williams and Hammond)
Intensity of peening—0.015A2 Thickness of Cr—0.006 in.
Deposits tested "as-plated" *i.e.* unground

Steel		Baking Time and Temperature (° C.)	Surface Condition	Fatigue Limit (tons per sq. in.)	Change, per cent	
Type	Lot				From electro-polished steel	From Datum
En25	1	nil	Anodically polished and plated	21.6	— 42.5	Datum
	1	200–1 hr.	Anodically polished and plated	15.0	— 60	— 30
	2	200–1 hr.	Shot peened and plated . .	39.5 ± 1	+ 8	+ 80
SAE 4340	1	nil	Anodically polished and plated	23.0	— 48	Datum
	1	192–8 hr.	Anodically polished and plated	14 ± 2	— 68	— 35
	1	192–8 hr.	Shot peened and plated . .	45.5 ± 1	+ 3	+ 95

conditions of deposition, the mechanical properties can be varied over wide limits, the values being generally similar to those of low- and medium-strength steels.

Nickel plating, like chromium plating, can cause a serious reduction in fatigue strength, this being largely due to the low inherent fatigue strength of nickel as normally deposited, relative to that of the steel substrate (*ca.* 13½ tons per sq. in. in unidirectional bending). In some circumstances nickel plating can also produce a marked reduction in ductility of the component arising from the absorption of hydrogen.

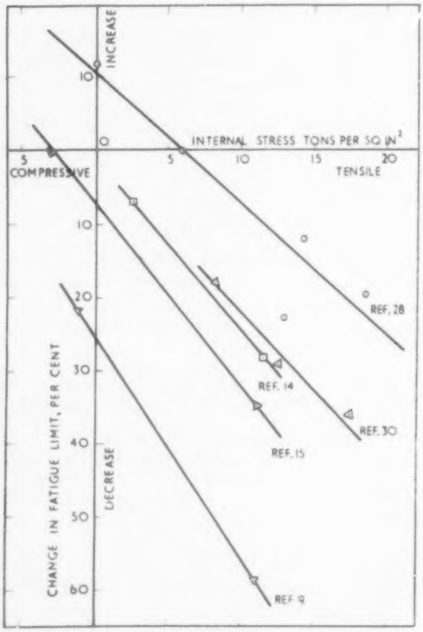
Few investigators appear to have studied the effect of thickness specifically but it has been reported from several sources that the percentage loss in fatigue strength increases with thickness of deposit. In this respect nickel behaves differently from unbaked chromium.

There is strong evidence that, as with chromium deposits, a linear relationship exists between the internal stress and the percentage loss of fatigue strength, as shown in Fig. 11.

The internal tensile stress in nickel deposits can be reduced or even reversed by the use of addition agents, but it should not be overlooked that addition agents, by increasing the fatigue strength of the nickel deposit itself could reduce the fatigue loss independently of the internal stress effect.

Fig. 11.—Linear relationship between the change in the fatigue limit of steel on nickel plating and the internal stress of the nickel deposit. (Williams and Hammond)

(Courtesy Institute of Metal Finishing)



Heat treatment at 130 to 200° C. after plating is frequently required for heavy nickel deposits to eliminate hydrogen embrittlement of the steel and to improve the adhesion of the deposit. There appears to be no firm information on the effect of this heat treatment on the fatigue strength, but it is unlikely that low temperature baking of nickel deposits will materially alter the loss in fatigue strength resulting from nickel plating in the conventional solution containing no addition agents.

The only data available on the effect of the strength of the substrate are those of Forsman and Lundin, and these suggest there is a linear relationship between the fatigue limit of the substrate and the percentage change in fatigue limit on plating. The properties of electrodeposited nickel range over far wider limits than those of chromium deposits however and it seems likely therefore that the position and slope of the line will depend on the thickness, tensile properties and internal stress in the nickel deposit.

As shown in Fig. 8 shot-peening to sufficient intensity either the steel base before plating or the nickel deposit after plating may eliminate the loss in fatigue strength.

3. Cadmium and Zinc

The most serious problem that arises from the application of cadmium and zinc to high-strength steels is that of hydrogen embrittlement of the steel —a subject on which there is an extensive literature. In comparison, the change in fatigue strength of a steel as a result of cadmium or zinc plating is relatively unimportant and probably for this reason the literature on this fatigue aspect is scanty.

Several investigators found a reduction in fatigue strength of about 5 to 15 per cent on cadmium plating. Wedden and Cooper however found that the process of anodic pickling and cadmium plating reduced the fatigue limit some 25 per cent, but, as in a comparable series of tests anodic pickling alone gave a similar reduction in fatigue strength it would appear that the cadmium plating itself had very little effect and that the reduction was due to the removal of surface compressive stresses during pickling.

Many investigations have been carried out with zinc deposits and all tend to show that zinc deposits of normal thickness do not reduce, and may even slightly increase, the fatigue limit of steel.

Cadmium and zinc are very weak and ductile, and when these coatings fail by fatigue, the fatigue cracks are unlikely to produce effective stress concentrations at the surface of the steel. It is unlikely therefore that they will have a direct mechanical effect on the fatigue strength of the steel base. Any reduction in fatigue strength is more likely to be due to the partial removal of

residual compressive machining stresses during the preparatory etching or pickling process.

Mechanism of Fatigue Failure

A full evaluation of the mode by which electrodeposited coatings alter the fatigue strength of metals would require a knowledge of the fatigue limits, under various conditions of mean stress, of (i) the substrate (ii) the coating and (iii) the plated metal. Gerber diagrams showing the fatigue strength under varying conditions of tensile and compressive mean stress (as Fig. 10) are available for bare steels and conform to a basic shape, but such diagrams are not generally available for electrodeposits themselves or for plated metals. Nevertheless it is possible to explain many of the observed facts on the basis of the knowledge already available.

Although the mechanical properties of conventional nickel and chromium deposits usually employed for engineering applications are generally quite substantial, their intrinsic fatigue strengths are low in comparison with those of most constructional steels. During cyclic stressing the first phase is the development of a fatigue crack in the coating which will act as a notch, concentrating the applied stress on the surface of the substrate at its root. On steels free from surface compressive stresses the crack will propagate into the steel, leading to fatigue failure when the stress concentration at the root of the crack reaches the fatigue limit of the steel.

When the steel contains residual compressive stress however, as induced by shot-peening for example, the compressively stressed layer will neutralise the tensile stress concentration at the root of the fatigue crack formed in the deposit, so that the steel will sustain a higher applied tensile stress without fracture *i.e.* to the level at which the resultant of the applied tensile and the residual compressive stress at the root of the notch equals the fatigue limit of the steel.

With the exceptionally weak and ductile coatings such as cadmium or zinc, fatigue cracks will presumably form in the coating at very low levels of cyclic applied stress, but the ready plastic deformation of these materials will prevent any effective stress concentration at the root of the cracks. From mechanical considerations therefore, as distinct from any pre-treatment involving etching, these coatings, *per se*, would not be expected to have an adverse effect on the fatigue strength of steels.

Hydrogen Embrittlement

In electroplating processes hydrogen may be introduced into the steel from two sources *viz*: (i) preliminary acid pickling and (ii) co-deposition of hydrogen during the plating process, the cathode efficiency for coatings in common use normally being substantially less than 100 per cent.

Hydrogen, especially in high-strength steels, may seriously reduce the ductility at low rates of strain as in the normal tensile test, and more important, can give rise to delayed failure (static fatigue) of high strength steels at stress levels far below the normal yield point. It seems generally recognized however that hydrogen embrittlement as a practical problem does not arise for steels of strength levels below about 80 tons per sq. in. TS.

Hydrogen has little effect on the normal mechanical properties of steel at stresses below the elastic limit, and it does not reduce the impact strength to any significant extent. Neither does it apparently affect the rotating bend fatigue strength of unnotched steels, but it seems possible that it may influence the fatigue strength of plated or notched steels, particularly at high levels. High stress concentrations at the root of machined notches, or fatigue cracks formed in a coating, are normally partially relieved by local plastic deformation of the steel, but absorbed hydrogen reduces the amount of plastic deformation the steel can withstand so that this form of stress alleviation cannot take place, and the effective fatigue strength of the part may be reduced.

The mechanism of delayed failure has been studied by Troiano and his co-workers and they suggest that a crack will initiate when a critical combination of hydrogen concentration and triaxial stress state is attained locally, *e.g.* in the vicinity of a notch.

Hydrogen produced by cathodic charging (analogous to conditions during electroplating) is at first largely concentrated on the surface layers of the steel, and on storage—or more rapidly on heat treatment—this hydrogen will be partly released to the atmosphere and partly redistributed by diffusion inwards, producing ultimately a lower and uniform concentration in the body of the steel. If a metal coating, *e.g.* nickel or chromium is permeable to hydrogen, release to the atmosphere can take place and low temperature heat-treatment for a relatively short time is effective in relieving embrittlement. The major problem arises with coatings that are impervious to hydrogen, notably cadmium and zinc especially when the whole area of the component is plated. In this case short period heat-treatment will merely serve to lower the concentration of hydrogen near the surface and to distribute it uniformly throughout the steel when it may still exceed the critical concentration.

Considerable effort has been devoted in recent years to minimizing the hydrogen uptake during pickling and cadmium plating and there is some doubt as to which of these processes is mainly responsible for embrittlement, and efforts have been

(*Continued in page* 756)

The Effect of Electroplating Processes on Fatigue etc.

(*Continued from page* 755)

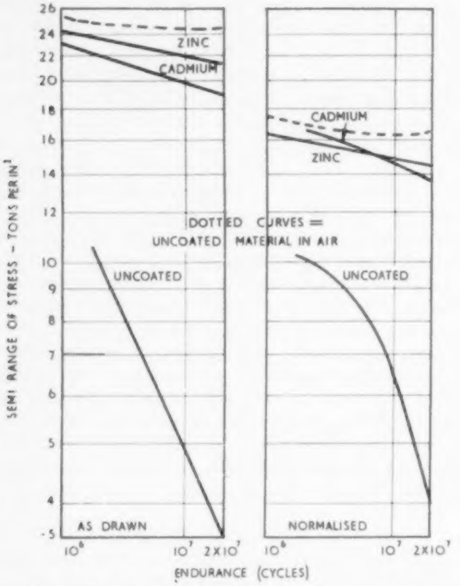


Fig. 12.—*Effect of zinc and cadmium plating on the corrosion-fatigue strength of steel.* (Sopwith and Gough)
(*Courtesy Iron and Steel Institute*)

made to formulate non-embrittling cadmium plating baths, to form porous (permeable) deposits, and to develop new steels which are less susceptible to hydrogen embrittlement.

Corrosion Fatigue

Coatings such as nickel or chromium which are cathodic to steel can be effective in combating corrosion fatigue only if they are continuous (*i.e.* free from cracks or pores) and remain so in service. However, since both these coatings have a relatively low intrinsic fatigue strength in comparison with medium and high strength steels, they will become discontinuous at a relatively low stress level owing to the development of fatigue cracks. These will permit access of the corrosive medium to the steel base at the root of the fatigue cracks where the cyclic stresses will be unusually high on account of the notch effect of the crack. Relatively weak coatings that are cathodic to the steel base are therefore likely to be only of limited value in preventing corrosion fatigue.

Anodic coatings (zinc and cadmium), which during the greater part of their life provide electrochemical protection to the steel exposed at discontinuities, would be expected to improve the corrosion fatigue strength and this has been confirmed by a number of investigators, notably Sopwith and Gough whose results are given in Fig. 12.

Conclusions

1. The fundamental limitation of electrodeposited coatings for engineering applications, *e.g.* nickel or chromium, is their low intrinsic fatigue strength (aggravated by their tensile internal stress) and a need exists for investigating the possibilities of electrodepositing stronger coatings. This is in fact feasible in the case of nickel by the use of suitable organic addition agents.

2. The loss in fatigue strength on chromium plating is markedly increased by a post-plating heat-treatment at 200 to 300° C. In the case of steels which can be heat-treated at 440 to 480° C. without loss of temper the loss in fatigue strength on chromium plating may be greatly reduced or even eliminated by baking at this temperature range after plating.

3. The loss in fatigue strength that occurs with nickel or chromium coatings can also be eliminated by shot-peening before plating, and components treated in this way can be baked after plating to remove hydrogen embrittlement without detriment to fatigue strength.

4. Coatings which are anodic to steel (*e.g.* zinc or cadmium), while they persist largely eliminate loss of fatigue strength under corrosive conditions; cathodic coatings (*e.g.* nickel or chromium) are of limited value for this purpose.

5. Although anodic coatings such as cadmium and zinc do not seriously affect the fatigue strength in air, the embrittlement of high strength steels arising from the absorption of hydrogen during pickling and the plating of these metals is at present difficult to avoid or eliminate.

Acknowledgment

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"ADVENTURE CENTRE" FOR YOUTH

SIR JOHN HUNT, Director, Duke of Edinburgh's Award, has opened the new "Adventure Centre" at Pont-y-Pant, near Betws-y-Coed, Wales, established by Tube Investments for its young employees of both sexes. The first of its kind started by a company, the Centre consists of a country mansion set in its own estate, from where mixed parties will be introduced, summer and winter, to mountain activities and skills of living in the open, etc.—the girls being expected to share equally in all the arduous exercises with the boys.

Large contingents of T.I.'s young employees have been preparing the mansion for its new purposes including the laying of new drainage, installation of central heating, and complete redecoration.

NEW GALVANIZING LINE IN OPERATION AT SHOTTON

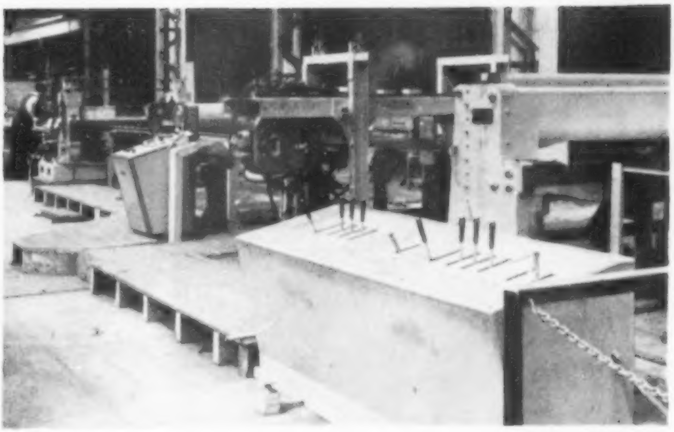
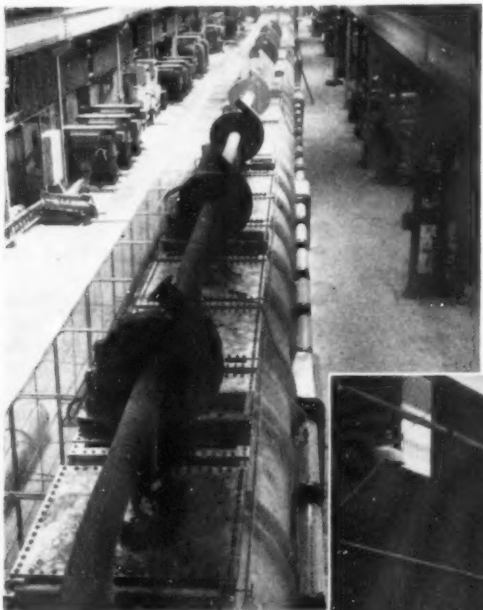


Fig. 1 (right).—Entry end of galvanizing line



TO meet the increasing demand for galvanized steel sheet and coil, and the changed pattern of the demand in recent years, John Summers and Sons Ltd. have started up a new continuous hot-dip galvanizing line at their works at Shotton near Chester. The company were already the largest producer of galvanized sheet and coil in this country, and the new line increases their production capacity by 50 per cent.

Galvanized sheet is virtually the only steel at present in short supply and John Summers anticipate a ready market for the increased output. Their tight-coated sheet, Galvatite, will be produced on the line, which is the fourth line operating at Shotton.

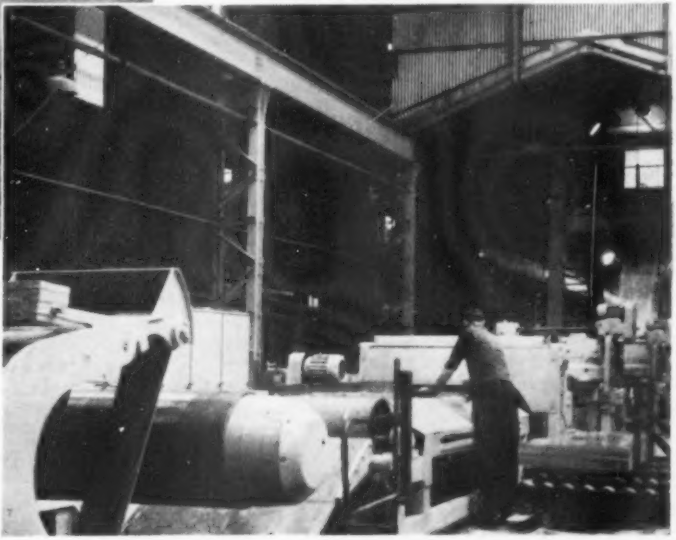


Fig. 2 (above).—General view of electric furnaces taken from exit end

Fig. 3 (right).—Exit end of line showing guillotine and (in foreground) the coiling equipment

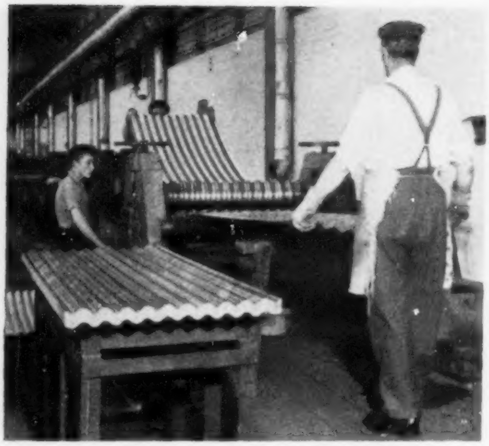


Fig. 4.—Curving machine for corrugated sheet

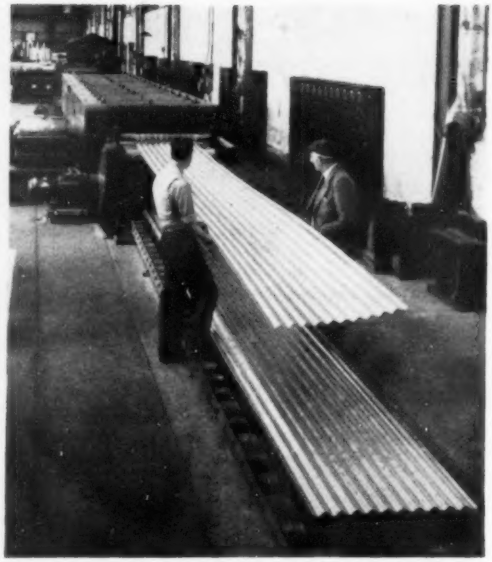


Fig. 5.—Corrugating machine. Note length of sheet being processed

The second continuous galvanizing line in the world—the first was in Poland—was installed by John Summers at Shotton in 1936. At first the output at Shotton was 100 per cent corrugated but the pattern of demand has so changed that today only 15 per cent is corrugated and the remaining 85 per cent is flat. This change has called for a greater uniformity and tightness of coat, as well as greater ductility, in galvanized sheet. Whereas many articles were made from black sheet and galvanized after fabrication, today they are made from pre-coated sheet. Further, the use of galvanized sheet is extending in new fields, particularly roll-formed sections, roof-decking and acoustic ceilings. This demands a coating which will stand up to forming.

The use of galvanized sheet for car underbodies is being considered by the British motor industry—a practice already prevalent in the United States (*see* Sheet Metal Industries, 1961, September).

This expanding use of galvanized sheet has called more and more for high quality, and with each of their lines installed since 1936 John Summers have sought to achieve the required tightness of coat and ductility, by control of heating and cooling. The second line started production in 1949 and the third in 1954.

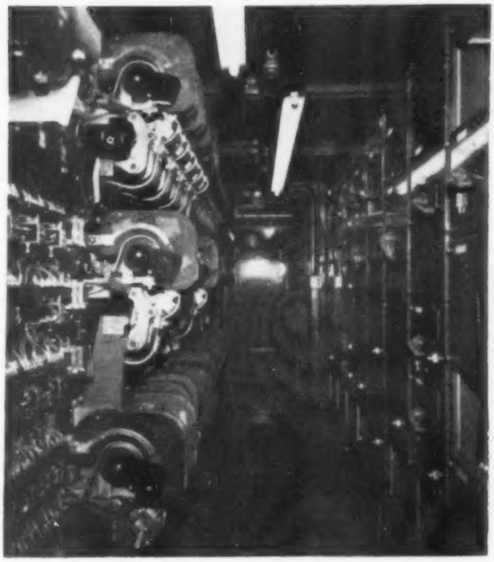
The new line which was designed by the company's chief engineer, Mr. R. L. Willott, and was mainly built by the company, will handle gauges from 2g. down to 14g. and coil and sheet up to 42 in. wide; this upper limit of width was chosen as the company already have a galvanizing line capable of handling strip up to 48 in. wide. The new line can operate at a speed up to 150 ft. per min. and incorporates a high degree of automation.

At the beginning of the line there are two uncoilers, a pinch feed roll, and a guillotine shear (all supplied by Brookes (Oldbury) Ltd.) and two Holden and Hunt 20-kVA spot welders, which run on a bridge over the line and are used for welding the tail of one coil to the lead end of the one following.

Strip passes over guide rolls from this point, through a further set of driven pinch rolls into a looping pit and from thence over and under and over three large-diameter tension rolls fitted with band brakes; all this equipment was supplied by Brookes (Oldbury) Ltd. The strip then passes into the furnace line. The first section is a preheating furnace, electrically heated; there are nine zones each temperature controlled and operating at a temperature of about 320° C. The main furnace, also electrically heated, consists of 25 zones and operates at a temperature of about 800° C. An interesting feature here is that about half of this furnace incorporates cooling coils through which air is circulated by centrifugal fans mounted on top of the furnace. By this means the temperature of the strip may be controlled before entering the galvanizing bath which is maintained at about 465° C. The main furnace has an atmosphere of cracked ammonia. Honeywell controls are provided for the furnace temperature control. From the furnace the strip passes into the galvanizing bath under a looping roll, and up through the surface of the bath between two rolls both of which have a shallow spiral groove machined in the roll face.

(*Continued in page* 760)

Integral Control of Rolling Mill



ONE of the American steel industry's first completely integral control systems is now in operation at the McDonald, Ohio, mills of The U.S. Steel Corporation.

The control cabin was placed over an open pit containing main power cables and control wiring for connexion to the panel-terminals in the control room. This construction reduced installation time considerably.

Operation of Coiling Line

A supply of hot rolled, cold coils is taken to the processing line by a conveyor ; a coil-tilter places an individual coil on the cradle-car for entry on to the mandrel of the process uncoiler.

The incoming small coil is uncoiled, levelled and end-sheared. The front end of one coil is then welded to the trailing end of a preceding coil to form one large coil, weighing up to 30,000 lb. An X-ray thickness gauge, installed in front of the shear, detects off-gauge portions of a coil which are cutout and the useable portions are welded into a continuous strip.

An oiling station coats the strip with a protective film prior to recoiling on the upcoiler, at which point banding is applied to the coil. An overhead crane, operated from the upcoiler control desk, carries finished coils away for further processing.

The framework of the new control cabin is of box-frame channel construction with transverse-channels back to back for the bottom floor and upper deck support. Vertical upright members are heavy angles and channels. Floor and upper deck plates are of four-way safety pattern and two flush doors permit access to the interior.

Direct current at 230 volts, available from an existing constant-potential shop supply, kept initial cost low and required a minimum space for mounting the electrical equipment associated with this new processing line installation.

The process uncoiler and leveller is driven by a 350-h.p. d.c. motor, with 125-h.p. motors driving the main pinch rolls and the upcoiler at the delivery end. Magnetic controllers with motor field control regulators are used on all three drives.

The steel strip is automatically controlled in two stages throughout the processing line. Tension regulation is used between the uncoiler and main pinch rolls. A photo-electric modulated control system is used for regulating the depth of loop with thinner strip. With heavy strip, tension is automatically regulated between the main pinch rolls and the upcoiler. Silicon controlled rectifiers supply the shunt fields of the main d.c. drive-motors. Regulating reference and feedback signals are compared in magnetic amplifiers for control of the rectifiers.

(*Continued in page* 760)

Fig. 1 (*top right*).—*Inside the control cabin*

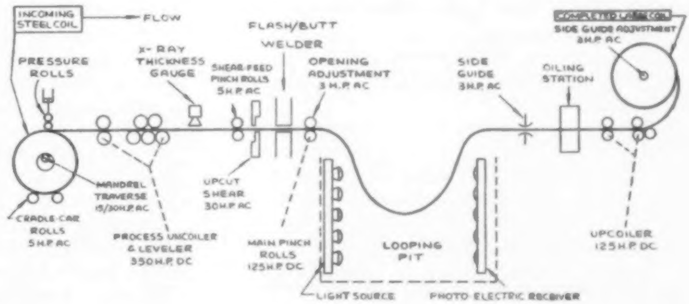


Fig. 2 (*right*).—*Schematic sequence of operations on the steel strip welding and coiling line*

The Inspection of Sheet Steel

(*Continued from page* 748)

tion of detecting laminations in sheet which has been rolled at temperatures where the lamination is softer than the steel, similar conclusions apply.

Ultrasonic Lamb Wave Techniques

Cold-rolled Sheet

Inspection techniques using Lamb waves are potentially suitable for steel sheet. The waves can be directed across the rolling direction thus scanning the maximum dimension of any lamination, and except for a zone of sheet beneath and immediately in front of the probe, the sheet can be inspected by scanning down one of its edges. The development of automatic scanning and recording appears to be possible although less simple than for the immersion transmission technique.

Attenuation limits the use of Lamb waves if the grain-size of the sheet is large.

Hot-rolled Sheet

As the grain-size in hot rolled sheets tends to be larger than that in cold-rolled sheets, the probability of the grain-size limiting the use of Lamb waves is greater.

Magnetic Techniques

Detection of defects is possible, but the method is slow and relatively insensitive.

Conclusions

The electrical-resistance, ultrasonic transmission, and ultrasonic Lamb wave methods can be successfully applied to the detection of laminations in cold-rolled sheets, the choice of method being largely governed by the amount of sheet to be inspected.

Potentially the ultrasonic Lamb wave method has advantages if automatic scanning and recording can be developed.

For the inspection of hot-rolled sheets the electrical resistance and ultrasonic Lamb wave methods are not recommended and the ultrasonic transmission method is not always suitable.

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New Galvanizing Line

(*Continued from page* 758)

The cooling tower is 75 ft. high from which the galvanized strip returns to floor level through three small undriven rolls set in triangular formation and then under and over two large-diameter driven rolls into two Ungerer roller levellers in tandem. These levellers are either or both used depending on the gauge of the strip and the amount of "skin passing" required.

At the end of the line the strip can be cut into sheets in a Brookes (Oldbury) guillotine shear and stacked or can be coiled by means of a Loewy coiler.

The total length of the line is about 400 ft. and equipment for speed control was installed by Lancashire Dynamo Electronic Products.

Additional equipment installed includes a new corrugating machine which can corrugate sheets up to 25 ft. long with high accuracy. This machine has 15 sets of rolls, the first set forming the centre corrugation on the sheet; subsequent sets make additional pairs of corrugations each side of the centre. This machine was supplied by Eichener Maschinenfabrik. A curving machine for corrugated sheets, built by Eichener, is also installed. A Robertson roller leveller feeds the flat sheets *via* a 26 angled-roller table into the corrugating machine.

Mill Line Control Cabin

(*Continued from page* 759)

Motor control centres, mounted along one side of the control room, provide motor protection and permit remote operation of the a.c. motors used throughout the processing line.

Mounted at one end and adjacent to the control centres is a transformer and selenium rectifier panel which supplies 40 volts for the jogging and threading operations of the three main d.c. drives.

The line is operated by three men from three individual control stations. The master desk, located about midway along the line in the area of the shear, welder and main pinch rolls, directs the operation of the entire line. Another man operates the control station at the uncoiler and the third man, with his control desk, is located at the upcoiler at the exit end of the processing line.

Manufacturer of the control cabin is the E.C. & M. Division of Square D Company, Cleveland. The British subsidiary, Square D Ltd, is at Swindon, Wiltshire.

INSTITUTE OF SHEET METAL ENGINEERING

Programme of 1961 Annual Conference

ANNUAL AUTUMN CONFERENCE

THE Annual Autumn Conference of the Institute of Sheet Metal Engineering, with which will be associated the twelfth Exhibition of Sheet Metal Working Equipment and Techniques, will be held this year at the Imperial Hotel, Birmingham, on Tuesday, November 7, Wednesday, November 8, and Thursday, November 9.

Programme

Tuesday, November 7

11.30 a.m. Official opening of the 12th Exhibition of Sheet Metal Working Equipment and Techniques in the Connaught Room of the Imperial Hotel by E. W. Hancock, Esq., O.B.E., President of the Institute.

2.15 p.m. 1st Technical Session—**General Presswork.** Paper: "Use of Dry Soap Film Lubricants for Deep Drawing" by J. Clarke (R. Cruickshank Ltd.)
Paper: "Tool Steels for High Speed Presswork" by A. W. F. Comley (Wilmot Breeden Laboratories).
Paper: "Methods of Rating Power Presses" by E. Hamilton (Wilkins and Mitchell Ltd.).

Wednesday, November 8

9.30 a.m. 2nd Technical Session—**Problems of Feeding in Modern High Speed Presswork.** Paper: "The Sprag Clutch as an Aid to Accurate Press Feeding" by E. E. Hempsall (Renold Chains Ltd.)
Paper: "The Swift Feeder Unit" by D. L. Dennison (Birmingham Tool and Gauge Co. Ltd.)
Paper: "The B.N.F.M.R.A. Roller Stretcher Machine as an Aid to High-Speed Press Feeding" by D. Boxall (British Non-Ferrous Metals Research Association.)

1.00 p.m. Buffet Luncheon.

2.15 p.m. 2nd Technical Session (continued).
Paper: "Problems Associated with the Production of Aluminium Pressings for Bottle Closures" by W. H. Hadley (Metal Closures Ltd.)
Paper: "Development of Roller Feed Mechanisms for Coiled Strip" by H. F. Hawkins and R. J. Lloyd (Humphris and Sons Ltd.)

Thursday, November 9

9.30 a.m. 3rd Technical Session—**Feeding, Slitting and Processing of Heavy Wide Coils in Rolling Mills, Press Shops and Warehouses.** Discussion on this highly topical theme will be initiated by the presentation of five papers outlining the relevant problems and techniques from the following differing points of view:

1. The Steel Strip Producer. S. Gray (John Summers and Sons Ltd.).

2. The Aluminium Strip Producer. R. W. Hilditch (Alcan Industries Ltd.).

3. The Equipment Manufacturer. J. F. Lyden (The McKay Machine Co., U.S.A.).

4. The Press Shop. D. C. Finch (Pressed Steel Co. Ltd.).

5. The Stockholder. A. I. Shenkman (Scottish Steel Sheet Co. Ltd.).

1.00 p.m. Buffet Luncheon.

2.15 p.m. 4th Technical Session—**Deformation of Metals at High Rates of Strain.**
Paper: "The Effect of Strain Rate on the Tensile Stress-Strain Characteristics of Metals, and some Practical Implications" by H. G. Baron (A.R.D.E.)
Paper: "The Rapid Determination of Strain Rate Effect Using a Dynamic Indentation Technique" by C. D. Davis and S. C. Hunter (A.R.D.E.)

Exhibition

The usual facilities will be provided for staging the Exhibition of Sheet Metal Working Equipment and Techniques, which has been a popular feature of the Annual Conference of the Institute for the past twelve years. A detailed programme and application form for tickets for the technical sessions will be circulated to all members in the near future. Non-members desirous of attending the Conference or of reserving space at the Exhibition, are invited to communicate with the Hon. Secretary of the Institute at John Adam House, 17/19, John Adam Street, London, W.C.2.

INTERNATIONAL DEEP-DRAWING RESEARCH GROUP

FOLLOWING the highly successful Colloquium on Forming and Testing of Sheet Metal held in Paris in May, 1960, it is planned to hold a further meeting in Düsseldorf on May 23 and 24, 1962, under the joint ægis of the International Deep Drawing Research Group and the Verein Deutscher Eisenhüttenleute.

It is proposed to devote the open sessions of this meeting to the presentation and discussion of papers on: (1) Speed Effects in Sheet Metal Forming and (2) The Influence of Surface Conditions on Deep Drawing.

Offers of papers (in English, French or German) or requests for further information regarding this meeting should be addressed either to: John Hooper, Esq., Secretary, I.D.D.R.G., John Adam House, John Adam Street, Adelphi, London, W.C.2, or to Geschaftsfuhrung des Vereins Deutscher Eisenhüttenleute, Düsseldorf, Breite Strasse 27.

FOR OUR OVERSEAS READERS

(Continued from page 703)

Résumés des Principaux Articles

résistance électrique, du flux magnétique, de la propagation d'ondes de compression ultrasoniques à travers la tôle, et également par la capacité que possède la doublure de réfléchir les ondes ultrasoniques de Lamb, se propageant le long de la tôle. On a pu évaluer ces méthodes en examinant un nombre de tôles laminées à chaud et à froid et en faisant la corrélation de ces observations avec un examen ultérieur destructeur.

L'effet des procédés de galvanoplastie sur la résistance à la fatigue et la tendance à la fragilité du substrat **page 749**

Par C. Williams

Les applications techniques des dépôts électrolytiques se limitent, pour la plupart, au traitement des pièces en acier; c'est sans doute pourquoi les livres se réfèrent très peu à l'action de la galvanoplastie sur les propriétés mécaniques des métaux non ferreux. Cet article porte donc sur l'acier en tant que substrat.

Pour les applications mécaniques, en tant qu'elles diffèrent de celles qui se rapportent à la résistance à la corrosion, il est essentiel que non seulement le revêtement même adhère fermement au métal de base, mais aussi qu'il possède de bonnes propriétés mécaniques. A condition que le contrôle de la galvanoplastie soit adéquat, la plupart des métaux déposés électrolytiquement peuvent avoir des propriétés mécaniques égales, et parfois supérieures au produit métallurgique correspondant, tandis que la résistance de la pièce sous une charge statique n'est pas, en général, influencée défavorablement par le dépôt électrolytique, à moins que la nature du substrat ne la soumette à une tendance à la fragilité causée par l'hydrogène libéré au cours des procédés de décapage et de galvanoplastie. Toutefois, sous l'effet de forces alternantes, les dépôts électrolytiques normalement utilisés comme apport ou en vue de créer une surface dure, tels le nickel et le chrome, réduisent très souvent d'une façon prononcée la résistance de l'acier à la fatigue. Toutefois, malgré la perte importante de résistance à la fatigue souvent rapportée dans les livres, et qui serait due à la galvanoplastie, on ne doit attribuer à cette dernière que très peu de défaillances au cours de l'emploi.

Zusammenfassungen der Hauptartikel

längs des Bleches fortschreitenden Lambschen Ultraschallwellen an den Schichtgrenzen beruhen. Die verschiedenen Verfahren wurden auf eine Reihe von warm- und kaltgewalzten Stahlblechen angewendet, die dann zwecks Kontrolle der Ergebnisse einer zerstörenden Werkstoffprüfung unterworfen wurden.

Der Einfluß von Elektroplattierverfahren auf Dauerfestigkeit und Versprödung der Unterlage **Seite 749**

Von C. Williams

Die ingenieurtechnische Anwendung der Galvanisierung beschränkt sich hauptsächlich auf die Behandlung von Stahlteilen, und wahrscheinlich aus diesem Grunde findet man im Schrifttum nur verhältnismässig wenige Hinweise auf die Auswirkungen der Plattierung auf die mechanischen Eigenschaften von Nichteisenmetallen. Im vorliegenden Artikel wird daher auch nur Stahl als Unterlage betrachtet.

Für die ingenieurtechnischen Zwecke ist es im Gegensatz zur korrosionsverhütenden Verwendung wesentlich, daß außer einer guten Haftung am Trägermetall gute mechanische Eigenschaften des Überzuges selbst verlangt werden. Bei passend eingeregelten Herstellungsbedingungen besitzen die meisten galvanisch niedergeschlagenen Metalle ebenso gute mechanische Eigenschaften wie die entsprechenden Hüttenerzeugnisse, manchmal sogar bessere. Die Festigkeit des behandelten Teiles unter statischer Belastung wird gewöhnlich nicht durch den galvanischen Überzug beeinträchtigt, vorausgesetzt daß das Trägermetall nicht von solcher Art ist, daß es durch den beim Beiz- und Niederschlagsprozeß freiwerdenden Wasserstoff spröde wird. Unter Wechselbeanspruchung bewirken die gewöhnlich für Auftragszwecke und zur Oberflächenhärtung benutzten galvanischen Schichten wie Nickel und Chrom meistens eine bedeutende Verringerung der Dauerfestigkeit des Stahls. So kann z.B. die Dauerfestigkeit eines hochfesten Stahls durch Verchromen unter besonders ungünstigen Umständen um nicht weniger als 80 Prozent abnehmen. Trotz der im Schrifttum so oft als Folge der Elektroplattierung hingestellten großen Einbuße an Dauerfestigkeit werden jedoch nur sehr wenige Betriebsstörungen direkt auf diese Ursache zurückgeführt.

Résumenes de los Artículos Principales

que se utilizan los cambios de resistencia eléctrica, de flujo magnético, en la propagación de ondas ultrasónicas de empuje a través de la chapa y por la habilidad que tiene una laminación para reflejar ondas de Lamb al propagarse por la chapa. Estos métodos han podido avaluarse examinando una cierta cantidad chapas laminadas en frío y en caliente y comparando los resultados con aquellos obtenidos más tarde por medio de ensayos destructivos.

El efecto de la electrodeposición sobre la resistencia a la fatiga y la aquebradización de las capas inferiores **página 749**

Por C. Williams

Las aplicaciones mecánicas de la electrodeposición están en general limitadas al tratamiento de piezas de acero y probablemente por esta razón existen relativamente pocas referencias en la literatura a los efectos de la deposición sobre las propiedades mecánicas de materiales no ferrosos. Este artículo trata por lo tanto del acero como base.

En la mecánica, a diferencia de las aplicaciones contra la corrosión, es esencial que, además de adherirse firmemente al metal de base, la deposición misma posea buenas propiedades mecánicas. Con un gobierno adecuado de las condiciones de deposición la mayoría de los metales electrodepositados puede producirse con propiedades mecánicas iguales, y a veces superiores a las del producto metalúrgico correspondiente, y la resistencia de la pieza bajo condiciones de carga estática no suele sufrir por efecto del electrodepósito, a menos que la naturaleza del metal base sea tal que esté sujeto a aquebradización por efecto del hidrógeno que se desprende durante los procedimientos de baño químico y electrodeposición. En condiciones de esfuerzos alternados, sin embargo, los electrodepósitos que generalmente se emplean para rellenar o endurecer las superficies, tales como el níquel y el cromo, suelen producir una importante reducción en la resistencia a la fatiga del metal. Sin embargo, a pesar de la gran pérdida en resistencia a la fatiga a que la literatura se refiere con frecuencia como resultado de la electrodeposición, muy pocos fallos en servicio se atribuyen directamente a la electrodeposición.

SHEET METAL NEWS

FEATURING EVENTS AND PERSONALITIES IN THE INDUSTRY

MODIFIED FINISHING SEQUENCE FOR NEW VAUXHALL VICTOR

New Finishing Coat Formulation and Body Design Assist in Production of Long-Lasting Finish

A MAJOR feature of the new Vauxhall Victor, shared also by the 6-cylinder models is the new hard, long-lasting, deep-lustre paint finish and the comprehensive under-surface protection.

This is the result of a three-year process development programme, with the objective clearly defined right from the earliest design stages. This programme involved:

1. The design of a body shell free from moisture-retaining recesses, shelves and corners—particularly underneath the body—and of panels on which paint would flow well and adhere strongly whether applied by dipping or by automatic or hand-spraying;

2. Revisions and improvements where appropriate to primer and surface costs;

3. The development of a new formula colour-finish to give the best lustre-retention properties and increased wear-resistance.

The body design aspect included a new approach to the floor pressings, replacing narrow indentations in the panels by shallow elliptically-shaped dished depressions, so giving a smoother, cleaner underbody of great strength. Wheel arches have been designed to eliminate corners and pockets which may trap mud thrown up by the wheels. Rebates and shelves have been eliminated wherever possible. New equipment has been installed to assist body shop inspectors to identify minor imperfections of metal-finishing.

Two additional processes are now included in the body protection sequence. The first is a new deep-dip in black primer paint, replacing the previous underbody dip, used by Vauxhall since 1952. The entire body, with the exception of the roof panel, is now immersed in a 5,000-gallon tank. Paint flows around the inner surfaces of the closed box-sections of the body-structure through holes designed solely for the purpose. There is an additional operation for the door-sills of the body. Into these polythene wax with an aluminium filler is pumped by special spray-gun, to protect the inside surfaces.

Second, an additional operation is now provided for the underside of the body, following the paint dip. After double-coats of red-oxide primer-surfacer and grey surfacer have been sprayed on the upper surfaces, a coat of red-oxide primer is sprayed all over the underside of the body, including the wings. This is the foundation upon which a 1/10 in. thick coat of bitumen-based compound is applied — standard practice since 1957 — to seal the underbody and wings and reduce road noise.

The new Vauxhall Victor

New Formula Synthetic Enamel

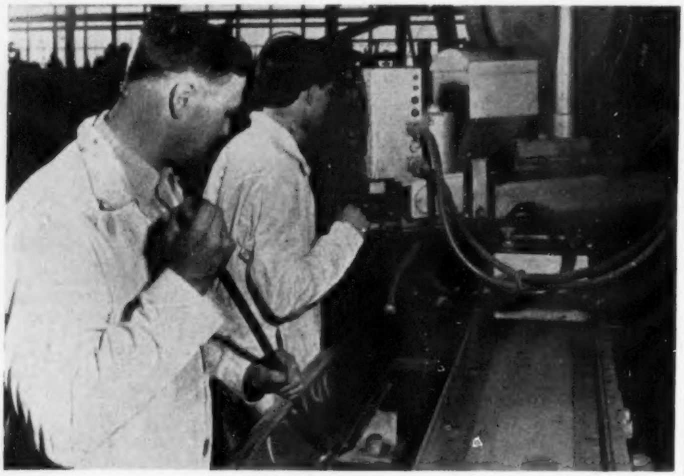
It is the third section of the development programme in which the biggest advance is claimed. This is the introduction to this country of a new-formula cellulose synthetic enamel, which has very satisfactory hardness and deep-lustre retention properties. Proved by practical usage in Britain and on the Continent, and by long-term exposure tests in several parts of the world, this new deep-lustre finish, on its ideal foundations, ensures that the new cars will keep their good looks for a very long time.

Every Victor body leaving the paint shop at Luton has been protected by the use of no less than 6¾ gallons of paint-protective, corrosion-resisting materials.

The sequence of operation is:—

1. Prepare bare metal.
2. Phosphate coating.
3. Joint-sealing.
4. Primer dip to roof level.
5. Red oxide primer surfacer all over—now including underbody and underside wings.
6. Grey primer surfacer.
7. 1/10 in. coat of tough bitumen/plastic on underbody and underside of wings.
8. Two double coats of cellulose synthetic enamel.
9. Polythene wax containing aluminium pigment pumped inside body door-sills.

JOIST AUTOMATIC WELDING AT NEARLY 50 in. PER MINUTE



FILLET welding of 8 ft. prefabricated joists for Acrow V form shuttering for concrete buildings is being carried out at the new Acrow plant in Saffron Walden, Essex, at welding speed of 49 in. per min. Making this possible is the Autopax submerged-arc automatic welding machine by Rockweld Ltd., Commerce Way, Croydon, Surrey.

In the Acrow plant, the Autopak set-up occupies a negligible floor space of some 200 sq. ft., and uses a 400-volt supply at 510 amp. Arc voltage is 29-30.

The Autopak is suitable for wire sizes from $\frac{3}{32}$ in. to $\frac{1}{4}$ in. with a corresponding range of welding currents between 200 and 1,200 amp, at an arc voltage adjustment between 25 and 40.

In addition to lowering welding costs, automatic welding with Autopak is also claimed to produce uniform, smooth and continuous welds. Chipping, grinding or cleaning are completely obviated and the appearance of the fabrication is greatly improved.

NEW WIRE GALVANIZING PROCESS

A VALUABLE new process for galvanizing steel wire has been introduced to this country by AEI-Birlec Ltd., the furnace manufacturing organization of Associated Electrical Industries Ltd. Originally developed in France, the new process offers both economic and technical advantages over the conventional sequence of annealing, pickling, fluxing and dipping.

Essentially, the Birlec process eliminates the pickling stages, both of which are costly and highly undesirable procedures. Instead, the wire is annealed in such a way as to permit its direct entry to the zinc bath at correct temperature, thus greatly reducing the heat input needed to keep the bath hot.

Besides the cost savings implicit in this simplification of the process, the running speed of the wire can be much higher than with the older method. This gives greater production from a given floor space and provides a much improved zinc coating on the wire with virtually no intermediate layer of zinc-iron alloy. Wire galvanizing by the Birlec process is claimed to withstand re-drawing or other severe forms of working which would cause flaking of a conventionally-produced coating. The quality of the product is claimed to be not only high but consistent, and both the thickness of coating and the hardness of the wire can be controlled to suit a range of specifications.

The first Birlec plant to operate this process is at present under construction: it will handle approximately $1\frac{1}{2}$ tons of wire per hour. Two similar installations have already been ordered for an overseas plant.

TALL TOWER FOR MOBIL OIL REFINERY

A STEEL fractionating column weighing 54 tons has been made at the Greenwich works of G. A. Harvey and Co. (London) Ltd. to the design and order of the Kellogg International Corporation for Mobil Oil's refinery at Coryton.

The column, which was completed on time to Kellogg's required delivery date, has a main shell 109 ft. long and 10 ft. in diameter. It is made of mild-steel plate $\frac{3}{4}$ in. thick and has at each end a dished and flanged head, spun and formed on Harvey's Rotarpress. Before leaving Greenwich the column was subjected to a hydraulic pressure test of 110 lb. per sq. in.

This fractionating column is the longest one fabricated by Harvey's for 18 months and represents an addition to the plant at Mobil's Coryton refinery, where it will be used in the processing of crude oil.

FIRST EXPORT ASSISTANCE REGISTER PUBLISHED

Free Guidance Offered to Over 500 Firms

DIRECTORS of more than 500 companies who have asked for export guidance have received a copy of Britain's first-ever "Export Assistance Register". The Register, published by the Institute of Directors' Export Action Now Committee, is compiled from answers to a questionnaire sent to the Institute's 37,000 members asking if their companies needed help to begin selling overseas or, alternatively, were able and prepared to give it.

Listed in the Register are some 600 companies who have offered export assistance to non-competing concerns. Copies of the first edition are available to interested Trade Associations on request from the Institute, 10 Belgrave Square, London, S.W.1.

EXTENSIONS FOR KEITH BLACKMAN

KEITH BLACKMAN LTD. of Tottenham, London, manufacturers of "Tornado" fan engineering and industrial gas equipment, have placed a further contract with Hale Construction Co. Ltd. for a new heavy fabrication shop and dust research laboratory. The contract is valued at £45,000 and is the second to be placed with Hale Construction Co. Ltd. as part of the company's expansion programme. The first contract, which is nearing completion, was valued at £25,000 and included two new buildings to house both finished goods and raw materials.

TELEVISION PIONEERS HOLD SILVER JUBILEE CELEBRATION

TELEVISION as we know it is 25 years old this year—thanks largely to Isaac Shoenberg and his team of research workers at Electric and Musical Industries Ltd.'s Hayes laboratories in the early 1930's.

To mark this anniversary, the press was recently invited to meet Mr. Shoenberg and some of his fellow pioneers in EMI's research building, where most of the early development work was carried out.

There are now 100 million television receivers all over the world and new transmitters are opening every month. But in 1936, when the B.B.C. first transmitted regular public high-definition television programmes, only 50 receivers existed. These were lent to employees of the few organizations in the television industry, to test reception in the London area.

It is not generally realized that the electronic system of television then used was the one developed by Mr. Shoenberg and his team. That system forms the basis of television as used throughout the world today, and the 405-line standard, which Shoenberg courageously adopted at a time when a much lower number of lines was considered to be sufficient, is still used in Britain.

The first television camera tube, an early camera and a 1937 television receiver, which showed the picture reflected in a mirror in the raised lid, were among several interesting items of equipment exhibited.

The prototype aerial mast for the one subsequently erected at Alexandra Palace still stands in the grounds adjoining EMI's research building.

A working demonstration was given of EMI Electronics Ltd.'s latest colour television system, which is being widely used industrially in this country and overseas.

Change of Name

THE Visco Engineering Co. Ltd., incorporated in 1921, has changed its name to Visco Ltd.

This company, which has been supplying, for the past 40 years, air filtration, fume removal, dust collection, water cooling and ventilating equipment to industry, will continue manufacturing these and other specialized equipment such as their recently introduced, Visco isokinetic fume sampling apparatus (V.I.S.A.), at their factories in Stafford Road, Croydon, Surrey and Port Causeway, Bromborough, Cheshire.

UNEMPLOYMENT INSURANCE AGREEMENT WITH THE FEDERAL REPUBLIC OF GERMANY

THE reciprocal Unemployment Insurance Agreement which the United Kingdom concluded with the Federal Republic of Germany on April 20, 1960, has been ratified and came into force on September 1, 1961. The National Insurance (Germany) Order, 1961 (S.I. 1961 No. 1513) price 6d.), obtainable from H.M. Stationery Office or through any bookseller.

The Agreement covers unemployment benefit provided under the National Insurance Scheme and the corresponding scheme in the Federal Republic. It enables an insured person who becomes unemployed in one country and claims benefit there to count any contributions he has paid in the other country.

A separate Agreement covering the other social security benefits of the two countries came into force on August 1, 1961. (The Family Allowances, National Insurance and Industrial Injuries (Germany) Order, 1961 (S.I.1961 No. 1202).).

Anyone who thinks he may be affected by either of the Agreements and who wants information should write to the Ministry of Pensions and National Insurance, Overseas Group, Newcastle-upon-Tyne.

Grades Appointed Exclusive Steel Peech & Tozer Stockholders

GRADES METALS LTD., of Steel House, Hanworth Lane Chertsey, have been appointed the exclusive Midland, Southern England and Wales stockholders for Steel Peech and Tozer. This departure in distribution policy for Steel Peech and Tozer, who are members of the United Steel Group, has come about with the coming into production of their new strip mill at Rotherham. The four-stand tandem mill is designed to roll mild steel up to 0.75 per cent carbon between 4 and 18 in. in width. Output thicknesses range from 0.010 to 0.160 in.

The small quantity user, as well as the bulk buyer, will now have the opportunity of purchasing the high quality steel produced at Rotherham, together with re-shearing facilities at Grades, to suit any particular customer requirements. Grades will continue to act as one of the major stockholders for the products of John Summers and Sons Ltd.

Change of Address

THE D.S.I.R. headquarters has moved to State House, High Holborn, London, W.C.1, telephone CHAncery 1262. State House is a new 15-storey block about three minutes walk from Holborn underground station on the north side of High Holborn.

SCOW EXPORTS TINPLATE TO U.S.A.

THE Steel Company of Wales is to start supplying regular shipments of tinplate to the U.S.A. During October and November 11,200 tons of tinplate will be shipped into San Francisco and other ports of the West Coast for delivery to the Continental Can Co. and the American Can Co.

To conform with the current trend in the U.S., the bulk of these orders will be delivered in coil form and will constitute the biggest output of coiled tinplate hitherto produced by the company, shown below being recoiled on one of the electrolytic lines.

APPOINTMENTS and STAFF CHANGES

Mr. Cecil F. Hurst has been appointed assistant managing director of **Samuel Osborn and Co. Ltd.** Mr. Hurst is now deputy chairman and assistant managing director of the company.

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Davy and United Engineering Co. Ltd., a member of the Davy-Ashmore Group, announce the following new appointments: Mr. S. Baker, M.A. (Cantab), general manager of the machinery division; Dr. R. B. Sims, Ph.D., B.Sc., M.I.Mech.E., director in charge of engineering; Mr. A. Thomas, F.C.I.S., A.A.C.C.A., secretary; Mr. G. L. Carswell, C.A., assistant secretary.

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With a view to ensuring more effective representation in England and Wales, some of the area representation of **Wild-Barfield Electric Furnaces Ltd.** has been re-arranged. The areas affected in which the undermentioned will also represent the Furnace Division of **G.W.B. Furnaces Ltd.,** are:

Bimingham and East Midlands: area manager, Mr. G. W. Haines; sales engineers, Mr. R. E. Butchers and C. A. McNeill.

West Midlands: Sales engineer, A. V. Skelsey.

South Wales: sales engineer, Mr. T. M. Morgan.

Sheffield and North Midlands: area manager, Mr. E. J. Heiser, M.I.E.E.; sales engineers, Mr. D. N. Greensmith and Mr. D. J. Sutherland.

Northern England: sales engineer, Mr. R. Flanagan.

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Mr. Robert Butler, previously a director of Quasi-Arc Ltd., has been appointed managing director of **Eutectic Welding Alloys Co. Ltd.** The company is part of the Eutectic/Castolin International Group which has fundamental and applied research laboratories in Switzerland and the U.S.A., with factories in fifteen countries, and distributors throughout the world.

* * *

The Incandescent Group of companies has appointed Mr. W. S. Sinclair to be manager of its Cardiff office. Mr. Sinclair, who has 12 years service with the company, is already well known in the South Wales area.

Associated Electrical Industries Ltd. has appointed as Director of Research Mr. L. J. Davies, who was director of research of A.E.I. (Rugby) Ltd.

Mr. Davies will be responsible for the direct supervision of the four A.E.I. research establishments at Aldermaston, Harlow, Manchester and Rugby.

Dr. J. E. Stanworth becomes the new director of research for A.E.I. (Rugby) Ltd; thus the directors of the A.E.I. research laboratories are: Aldermaston, Dr. T. E. Allibone; Manchester, Dr. J. M. Dodds; Harlow, Dr. M. E. Haine; Rugby, Dr. J. E. Stanworth.

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Edgar Allen and Co. Ltd. announce that Brigadier A. Levesley, O.B.E., M.C., T.D., M.I. Mech.E., has accepted the chairmanship of the **Sheffield Standing Conference of Voluntary Youth Organizations** in succession to the former Chief Constable of Sheffield, Mr. G. E. Scott, O.B.E.

* * *

Mr. H. Johnson and Mr. H. B. Travis have joined **Suffolk Iron Foundry (1920) Ltd.** as area technical representatives.

Mr. Johnson, is the technical representative for Lancashire and the North West Coast, and Mr. Travis, the Yorkshire and North East Coast technical representative.

* * *

The George Cohen 600 Group Ltd. have appointed Mr. Peter Bonner, B.Sc., A.M.I.Mech.E., A.M.I.Prod.E., to the board of their associate company, **T. C. Jones and Co. Ltd.**

Immediately prior to joining T. C. Jones and Co. Ltd., Mr. Bonner was with Ashmore, Benson, Pease and Co. Ltd., members of the Davy-Ashmore Group.

* * *

Mr. John Blinch has joined the board of **Industrial Education International Ltd.** and its associated company **Materials Management International Ltd.,** and will be responsible for the work of these two organizations in Europe.

* * *

The directors of **The Pyrene Co. Ltd.** have appointed Mr. H. A. Holden (manager, Metal Finishing Division) as a divisional director. Mr. Holden has been closely associated with the study of corrosion and metal finishing for many years.

Mr. A. Nicholson (chief chemist) has been appointed a divisional director (Chemistry).

Mr. Nicholson joined the company in 1939 and was appointed chief chemist in 1943. He will now be responsible for the direction of the company's chemical activities.

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Mr. E. J. Robinson has been appointed a director of **The Head Wrightson Export Co. Ltd.,** which is responsible for the development of trade in overseas markets for the Head Wrightson companies.

Mr. R. F. N. Otway has joined the company as manager—Europe. Before taking up this appointment Mr. Otway was with The Morgan Crucible Co. Ltd.

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Mr. D. R. Walker, A.C.C.S., has been appointed secretary of the **Vitreous Enamel Development Council,** and the registered offices have been transferred from 11 Ironmonger Lane, London, E.C.2, to 28 Welbeck Street, London, W.1 (Hunter 2237). The general manager of the Council is Commander G. Clarke, F.C.C.S.

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The Council of **The Iron and Steel Institute** are to nominate Mr. M. A. Fiennes, M.I.Mech.E., group managing director of Davy-Ashmore Ltd., at the Institute's autumn general meeting on November 29, 1961, for election at the annual general meeting on May 2, 1962, as President for 1962-1963.

Mr. H. W. A. Waring, C.M.G., general managing director and deputy chairman of GKN Steel Co. Ltd., has been elected hon. treasurer of the Institute, in succession to Sir Julian Pode, deputy chairman and managing director of The Steel Company of Wales Ltd. Sir Julian, who had served as hon. treasurer since 1959, was elected a vice-president of the Institute.

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Trico-Folberth Ltd., screen-wiper and washer manufacturers, announce the appointment of Mr. R. Hadekel as chief engineer. Mr. Hadekel was formerly an engineering consultant with the Sperry Gyroscope Co. Ltd.

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Mr. J. F. Summerfield and Mr. D. G. Lambert have joined **J. A. Hemming Ltd.,** steel stockholders, of Birmingham and Oldbury, as additional members of their outside sales staff. Both have previously been employed by cold-rolled steel strip manufacturers.

(*Continued in page* 767)

Appointments and Staff Changes

(*Continued from page* 766)

Further senior appointments at Spencer Works, now under construction at Llanwern, near Newport, Mon., are announced by **Richard Thomas and Baldwins Ltd**: Dr. A. J. Kesterton, M.Eng., Ph.D., F.I.M., assistant general manager; Mr. C. Gilbert, B.Sc., chief quality inspector; Mr. J. Morris, B.Sc., M.Sc., chief metallurgist; Mr. I. Penberthy, chief chemist; Mr. A. G. L. Kenny, chief safety engineer.

* * *

Mr. K. F. Tunnicliff has joined the Midlands staff of **Desoutter Brothers Ltd.,** in addition to Mr. M. Giles, Mr. H. Jones and Mr. D. W. G. Smallwood, operating from the Birmingham office.

In the North-East Mr. E. Machan has replaced Mr. J. Fox who has transferred to North East London to take over from Mr. C. L. Startup, who has retired.

A new appointment is Mr. P. C. Botting, who will be responsible for the Central London area.

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The United Steel Companies Ltd. announce that Mr. N. D. Macdonald, general works manager of their Workington Iron and Steel Co. branch, has been appointed a director of that branch.

* * *

At the annual general meeting of the **Scienti ficInstrument Manufacturers' Association of Great Britain,** Mr A. W. Jones (Fleming Radio (Developments) Ltd.) was installed as president for the year 1961-62 by Mr. G. C. Ottway (W. Ottway and Co. Ltd.), the retiring president, who now becomes a vice-president.

Other honorary officers elected were: Mr. R. E. Burnett (Marconi Instruments Ltd.), vice-president and president-elect; Mr. G. C. Ottway (W. Ottway and Co. Ltd.), vice-president; Major Wm. Logan (Avo Ltd.), hon. secretary; and Mr. G. S. Sturrock (Kelvin and Hughes, Ltd.), hon. treasurer.

PRODUCTION EXHIBITION

THE Fifth Production Exhibition will be held in the National Hall, Olympia, from April 30 to May 5, inclusive in 1962.

THANKS!

TO United Steel Companies Ltd. and to David King, thanks are once again expressed for their hospitality at the Farnborough Air Show.

"CENTURY 21 EXHIBITION"

THE Central Office of Information advise that the Americans are planning an exhibition in Seattle, U.S.A., next year which will be on a scale similar to that of the World Exposition in Brussels in 1958.

Many nations, including Great Britain, will be taking part, and this exhibition—to be known as the "Century 21 Exhibition"—will be held from April 21 to October 21, 1962.

Members of the Gauge and Toolmakers' Association who have developed a gauge, tool, measuring instrument, or other precision item which they feel would qualify for display in the British Pavilion are invited to send full details very quickly to R. J. Reeves, Esq., Exhibition Division, Central Office of Information, Hercules Road, London, S.E.1.

TEACH DON'T PREACH

SAFETY posters often come in for adverse criticism especially the "don't do this or that" type.

Such criticism, say the British Safety Council, is justified. "The best way to educate is to teach, not preach", says the Council's National Director, Mr. L. D. Hodge. The Council believe that "teaching" posters can play a valuable part in industrial safety, and have recently launched a new "Case History" series along these lines.

The new posters—the first four are being distributed to over 7,000 factories and work places in Great Britain—illustrate the cause of common accidents, and suggest their simple prevention. The series will cover all aspects of safety in industry, and will be invaluable to safety officers dealing with new employees and apprentices say the Council.

ELECTRONIC BATCH COUNTERS HELP SPEED CAP PACKAGING

AN installation for the accurate counting and packing of bottle and jar caps has been made at the Poole factory of the Wallis Tin Stamping Co. Ltd. Caps, which may be of any size or shape, coming from the cap-forming machines are fed onto a conveyor belt along one side of which are situated a bank of standard B.C.4. electronic photocell Decade Batch Counters. Guide rails on the conveyor belt divert streams of caps to each of the batch counters which simultaneously deal with the whole output. The caps, on diversion, are passed through a light beam in the photo-cell and light heads and are then allowed to pass down the output chute into the waiting fibreboard container. In passing through they break the light beam and thus cause a count to be registered.

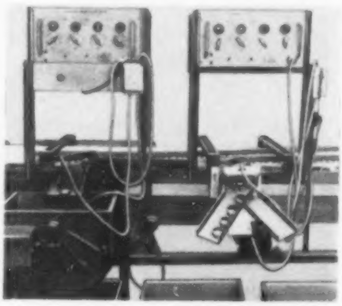
There are two alternative forms of final output situated after the photocell and light heads, both of which can be seen in the illustration. In the first, caps fall into the hopper and on through a trap into the waiting container below. On completion of the "batch" a shutter closes over the trap while the filled container is replaced by an empty one. After a pre-determined time interval has elapsed the shutter opens and allows the accumulated caps to drop into the new container, thus the cycle is recommenced without breaking the flow.

The second and alternative method (seen on the right of the illustration) consists of two output chutes with a gating mechanism. The caps, after passing through the light beam, are diverted down one of the output chutes and thence into the waiting container. On completion of batch the gating mechanism then diverts the flow of caps into the other output chute which then fills the second container while the first one is replaced.

These electronic batch counters are normally working on this application at the rate of 125 per minute but are capable of considerably higher speeds.

This electronic equipment is designed and manufactured by Electronic Machine Co. Ltd., Mayday Road, Thornton Heath, Surrey.

Batch counters



Institution of Production Engineers Awards, 1959-60

THE Council of the Institution of Production Engineers has approved the following Medal Awards for 1959-60:

Silver Medal for the Best Paper presented to a Section or Region of the Institution by a Member: Mr. K. J. Hume, B.Sc., M.I.Mech.E., M.I. Prod.E., Reader in Engineering Production Technology at the Loughborough College of Technology, for his paper on "Developments in Dimensional Accuracy".

Silver Medal for the Best Paper presented to a Section or Region of the Institution by a Non-Member: Mr. E. P. Ward, senior consultant, Martech Consultants Ltd., for his paper on "National Character Dictates Production Methods".

The J. D. Scaife Silver Medal Award for the Best Paper published in the Journal of the Institution, 1959-60, *other than those presented to Section and Regions; or Named Papers*: Mr. H. Grisbrook, B.Sc. (Birm)., A.M.C.T., Department of Engineering Production, University of Birmingham, for his paper on "Precision Grinding Research".

BLACK AND DECKER EXPAND LONDON SERVICE FACILITIES

A NEW service branch has been opened by Black and Decker Ltd., at 1 Brixton Road, London, S.W.9. Designed to expand the company's service facilities in the London region—it is the third in the area—it will be known as the South London service branch. The new branch is intended for servicing industrial power tools, service users and the home user.

The two other London branches at Harmondsworth and Holloway Road will now be known respectively as London West branch and London North branch.

Mr. C. W. May, previously branch service engineer at the Holloway Road branch, has been appointed branch service engineer of the new branch.

Mr. W. Hickie will replace Mr. May as branch service engineer of the Holloway Road branch.

Extension of Telex for Fenner

THE Glasgow branch of J. H. Fenner and Co. Ltd. is now on Telex. The number is 77269. This service extends the Telex facilities already at Hull, Birmingham, London and Manchester.

BRONZE WELDING SAVES RACING DRIVER

THE illustration shows a close-up of the bent chassis members at the front of the Lotus Formula I racing car, driven by Innes Ireland, which crashed recently at Monaco. The joins, which were welded using Bronzecraft No. 3 nickel-bronze rods and the Gasflux process, remained unbroken, thus saving the driver from further serious injury. Bronzecraft nickel-bronze rods and the Gasflux equipment are manufactured by Weldcraft Ltd., Slough, Bucks.

COMPUTOR SYSTEM CONTROLS BASIC OXYGEN STEEL FURNACE PLANT

INTERNATIONAL SYSTEMS CONTROL LTD. of Wembley announce that Thompson Ramo Wooldridge Inc. of Los Angeles (which, with the General Electric Co. Ltd. of England is jointly interested in I.S.C. Ltd.) has received an order from the Great Lakes Steel Division of the National Steel Corporation for a computer system to control the world's largest basic oxygen steel furnace plant at Detroit. The computer will take into account all the characteristics of the raw material and the furnace, as well as the specification for the end product.

The computer will determine the amount of raw materials required and prescribe the amounts and types of additives necessary to produce a given quantity of finished ingots of the right specifications. It will take care of the furnace process, controlling the heat generated by adjusting the flow rate and duration of the oxygen blow. Besides maintaining a consistent product of top quality this precise control also ensures the minimum consumption of raw materials and oxygen.

From the data which the computer automatically records, a close relationship between furnace conditions and finished ingot characteristics can be drawn up, for use in determining the optimum conditions for subsequent batches. At the same time the computer's programme can be automatically revised as more is learnt about the furnace operation.

The whole of the information on this installation will shortly be available for use by International Systems Control Ltd., in the same way that the details of earlier Thompson Ramo Wooldridge projects in the chemical, oil, nuclear, electric power and other fields are available to the joint company, to be applied to similar plants in the U.K., the EFTA countries and the Commonwealth.

ACCUMULATOR PRICES REDUCED

FAWCETT PRESTON & COMPANY of Bromborough, Cheshire, a member of the Metal Industries Group, announces reductions of between 5 and 33 per cent in the price of its entire range of Greer-Mercier hydro-pneumatic accumulators and alleviators. The reductions have been made possible by the standardization of the range to 18 models.

BERYLLIA-FREE MALLORY 73 BERYLLIUM COPPER

JOHNSON MATTHEY announce that in future all Mallory 73 beryllium copper strip up to 0.025 in. thick will be supplied with beryllia-free surfaces. This will reduce tool wear without affecting the mechanical properties of the alloy.

Undue tool wear is attributable to the presence of beryllia, a hard and abrasive oxide of beryllium that is formed during the solution heat treatment of the alloy. The oxide is colourless and is not removed by normal cleaning or pickling methods, so that it is often present on material that appears to have a good surface finish.

A new process developed by Johnson Matthey completely removes beryllia, and the improved material is supplied at no extra cost.

DESIGN APPRECIATION COURSES

CONTINUING its efforts to bridge the gap between industrial design and engineering, the Council of Industrial Design is to cold two more design appreciation hourses for engineers in the autumn.

A staff course will be held in two phases (October 23-27 and November 20-24) and one for executives from November 27 to December 1. Both will take place in the London area and, so as to make the fullest use of available time and encourage group discussion, will be residential.

Early reservation is recommended as the number of course members is limited to permit adequate discussion. Forms are available from Miss Sydney Foott, Education Officer, CoID, 28, Haymarket, London, S.W.1.

NEW STEELWORKS AUTOMATION COMPANY

THE AEI/Davy-United Steelworks Automation Unit, which was formed in July 1960 to apply automation to the processing of steel and non-ferrous metals, will henceforth trade in its own right.

The interests of Associated Electrical Industries Ltd. and Davy-Ashmore Ltd. in this field are now combined in a jointly owned company, Davy-AEI Automation Ltd.

The chairman of the new company is Mr. M. A. Fiennes, managing director of Davy-Ashmore Ltd., and the vice-chairman is Mr. C. R. Wheeler, vice-chairman of Associaated Electrical Industries Ltd.

The headquarters of the company will be located at Booths Hall, Knutsford, Cheshire.

SOLARTRON OPEN NEW EXTENSION

THE second phase of the Solartron Electronic Group building programme was opened recently by the Rt. Hon. Reginald Maudling, M.P., President of the Board of Trade. The new building consists of a four-storey block of 35,000 sq. ft. and 70,000 sq. ft. of production floor space and will be the main administrative, research, development and electronics manufacturing centre. Two further phases are planned and the company hope to double their existing factory area by 1965 or 1966.

A large gathering of people from the press and from industry witnessed the opening ceremony and were allowed to inspect the new building. Many of the company's systems and equipments were demonstrated in the area of the workshops where they are manufactured while others were contained in a special exhibition area.

STEEL CO. OF WALES TO INSTAL NEW GALVANIZING PLANT

THE Head Wrightson Machine Co. Ltd., Middlesbrough, a subsidiary of Head Wrightson and Co. Ltd., have received an order from the Steel Company of Wales for an Armco-Sendzimir continuous hot-dip galvanizing plant to be installed at Abbey Works, Port Talbot. The Head Wrightson Machine Co. are the main contractors for the plant and will be responsible for the design and engineering. The furnace for annealing and surface preparation will be built by AEI-Birlec.

The plant will be capable of galvanizing cold-reduced strip up to 54 in. in width and from 0.015 to 0.062 in. thick at a processing speed reaching 150 ft. per min.

This line will incorporate all the latest developments in continuous galvanizing and will be designed by The Head Wrightson Machine Co. in conjunction with their American associates Blaw Knox Company, Aetna Standard Division, who claim to have built more than half of the continuous galvanizing lines at present in operation throughout the world.

The total value of the contract, excluding the civil work and electrical equipment, is approximately £500,000.

HEDIN ACQUIRE MORE ACCOMMODATION

HEDIN LTD., of South Woodford, manufacturers of industrial electric heating equipment, announce that as a result of continued expansion of their business they have taken over additional office and works accommodation at Fowler Road, Hainault, Essex.

The manufacture of industrial heating elements and resistances will continue to be carried out at South Woodford while furnaces and ovens will be made at Hainault.

Although the company was formed in 1930, it is only in the last six or seven years, under the direction of Mr. James Royce, that considerable progress has been made in the development and manufacture of electric furnaces. To enable Mr. Royce to devote even more time to research and development work, Mr. Dennis Hobson has been appointed sales manager of the Furnace Division.

The sales of industrial ovens will continue to be handled under the managership of Mr. Peter Keen.

The increased works capacity will enable the company to undertake the fabrication of much larger and more highly mechanised heating equipment, and eventually to extend their activities to cover fuel-fired as well as electrically heated equipment.

A New Cold-Forging Plant In Germany

THE Camp Bird Group of companies announces the opening and start of production of a new £500,000 factory in West Germany, for cold-forging plant. It is a member of the International Cold Forging Group whose factories are situated at Ravensburg (Germany), Monaco, and at Sunbury-on-Thames in the U.K. The new factory is located at Lockweiler between Saarbrücken and Trier, and will be known as Saarländische Werkzeug und Maschinenfabrik, Walther Nothelfer G.m.b.H.

Apart from the manufacture of cold-forging equipment for direct sale, it is also planned to maintain a complete cold-forging installation in production as this will enable customers' plant to be proved under actual operating conditions.

The works comprise two ground level buildings of 40 by 180 ft. and 177 by 184 ft. respectively. A third single-storey building is nearing completion. The smaller building houses the materials store, heat treatment plant, phosphating installation and ancillary services. The large building contains the machine shops, the assembly bays for cold-forging equipment and two 12-ton travelling cranes.

Connection of the private rail sidings to the Federal German Railway line which runs behind this site, is already planned.

Modern housing accommodation is being provided to facilitate recruitment of a suitable skilled labour force which is expected to total about 500 in a relatively short time.

SCOTTISH REFRESHER COURSE

THE Institution of Plant Engineers announce that the next of its comprehensive refresher courses for Works and Plant Engineers is to be held in Scotland this winter, at the Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow.

Sponsored by Sir Andrew McCance, D.Sc., LL.D., F.R.S. (Chairman of Colvilles Ltd. and Chairman of the Board of Governors of The Royal College of Science and Technology), and available to all engineers who wish to take advantage of it, the course comprises 18 weekly lectures on Wednesday evenings, commencing November 1.

Copies of the syllabus and full particulars may be obtained from the Secretary to the Refresher Course, 39 Elmbank Crescent, Glasgow, C.2.

IMPROVEMENT OF ZINC RICH PAINTS

THE Zinc Pigment Development Association announce that the three of its members who manufacture zinc dust pigments have been awarded a contract by the expanded research programme of the American Zinc Institute and Lead Industries Association to carry out a joint programme of research to improve the characteristics of zinc-rich paints. Most of the practical work will be carried out in the research laboratories of the Imperial Smelting Corporation Ltd. at Avonmouth, with the assistance of Amalgamated Oxides (1939) Ltd. of Dartford, and Durham Chemicals Ltd. of Birtley. A committee representing all three companies and the Zinc Development Association will meet frequently to guide the research.

Initially attention will be given to developing better paints for the priming of motor-car underbodies. Zinc-rich paints are already finding extensive use for this purpose in the U.S.A., where the vast quantities of salt used each year to remove snow in the northern cities have created a serious corrosion problem with chassisless construction. With the co-operation of the motor industry it is hoped to be able to formulate paints with better adhesion, flexibility and welding characteristics than those currently available. Later on, work will be done on paints for structural steelwork and marine applications.

The expanded research programme was established in 1958 to sponsor fundamental and applied research on zinc and lead with a view to developing the uses of the metals and their derivatives. The programme is supported by metal producers and mining companies in the U.S.A. and the British Commonwealth and is being carried out in several countries. The zinc and lead industries will make the results available for the benefit of the whole of the industries concerned.

REFINING PRECIOUS METALS

APPROXIMATELY 35 per cent of the free world output of platinum group metals, together with substantial amounts of gold and silver are produced from the complex sulphide ores mined by Inco in Canada.

These ores, mined mainly for their nickel and copper content, contain trace elements of the platinum metals, gold and silver, which are separated from the residues of the nickel and copper refining processes. A new 16 mm. colour sound film describes the intricate processes employed to refine gold and silver in Canada and platinum, palladium, rhodium, ruthenium and iridium at the Acton refinery of The International Nickel Co. (Mond) Ltd., in the United Kingdom.

The film illustrates the chemical processes in detail and many animations are used to assist an understanding of the complex chemical reactions involved. It lasts for 29 minutes and is obtainable on free loan on request from the Publicity Department. The International Nickel Co. (Mond) Ltd., 20 Albert Embankment, London, S.E.1.

MERSEYSIDE'S FASTEST FACTORY CONSTRUCTION

PRODUCTION has started—two months before final completion—at Merseyside's new £3½ million domestic appliances factory at Kirkby near Liverpool. This is one of the fastest factory construction projects ever carried out in the area, say the builders, Holland and Hannen and Cubitts (North West) Ltd. of Bromborough, Cheshire. Work on the 422,000 sq. ft. factory for Fisher and Ludlow Ltd. started last May and the project is due for completion in the autumn. Already seven of the 17 bays in the main production building have been handed over.

Forthcoming Events . . .

October 4

Institution of Production Engineers (North Midlands Region) "The Application of Spark Machining to Die Making in Different Industries," by J. P. Blackshield, at the Nottingham Reform Club, Victoria Street, Nottingham. 7.0 p.m

October 10

Institution of Production Engineers (East and West Ridings Region). "Cold Extrusion," by H. A. J. Dennison, at the Technical College, Waterdale, Doncaster. 7.0 p.m.

Institute of Sheet Metal Engineering (South-West Branch). "Roll-Forming and Draw-Bench Section," by P. Keeler and L. Gibbs, in the Engineering Lecture Theatre, Bristol University. 7.0 p.m.

October 11

Institute of Sheet Metal Engineering (Midland Branch). Works visit to Stewarts and Lloyds Ltd., Bilston.

October 12

Liverpool Metallurgical Society. Presidential Address—"Metallurgy and the Craftsman," by F. R. Brace, at Dept. of Metallurgy, The University of Liverpool, Liverpool 3. 7.0 p.m.

Institution of Plant Engineers (Sheffield and District Branch). "Problems in Rolling Mills," by W. Bailey, at the Blue Bell Hotel, Scunthorpe. 7.30 p.m.

October 25

Institute of Sheet Metal Engineering (Wolverhampton Section). Works visit to Rubery, Owen and Co. Ltd., Darlaston.

Institute of Sheet Metal Engineering (North-West Branch). "Development and Building of Large Power Presses," by E. Hamilton, in the Engineers' Club, 17 Albert Square, Manchester. 7 p.m.

Institution of Production Engineers (North-West Region). "Explosive Forming," by Dr. W. S. Hollis, at Reynolds Hall, Manchester College of Technology, Sackville Street, Manchester. 7.15 p.m.

JOINT U.S.-DOMINICAN REPUBLIC MINING AND STEEL PROJECT

AN agreement has been signed between the Dominican Republic Government and the Chicago firm of Meissner Engineers Inc. for the establishment of a major mining and metal-producing enterprise, with 51 per cent of the assets owned by the Dominican State.

The investment in capital equipment will be in the region of $60 million and will include a railway and a new port at Punta Gorda. The first stage will be the exploitation of the large iron ore deposits in the Provinces of Sanchez Ramirez and Duarte. It is estimated that an annual production figure of 5 million tons of ore will be achieved soon after shipments commence in 18 months' time and it is possible that this may be doubled three years from this date.

The enterprise plans to establish an iron and steel industry in the near future which will produce steel sheet and constructional materials.

Work on mining and transport installations will commence before the end of the year and will employ 3,000 workers which will also be the number of permanent workers needed by the industry. Arrangements are being made to train Dominican technicians at the University of Santo Domingo with assistance from the Massachusetts Institute of Technology.

New Work in Europe

SCHLOEMANN AKTIENGESELLSCHAFT, Düsseldorf, are building for the Salzgitter steelworks a shear line for side-trimming and cross-cutting cold-rolled steel strip from 0.014 in. to 0.120 in. thickness, up to 6 ft. 8 in. width, in coils weighing up to 30 tons, and for strip speeds up to 325 ft./min. It is scheduled for operation early in 1962. Schloemann have also been awarded a contract by Salzgitter for the manufacture of a plant for slitting and recoiling cold-rolled steel strip. It is to have the same capacity as the aforementioned shear line and will be laid out to deal with material travelling at up to 1,000 ft./min. This installation is expected to be completed late in 1962.

Schloemann are also building for the Bremen mill of Klöckner-Werke Aktiengesellschaft five side-trimming and cross-cutting shear lines for cold-rolled steel strip to be laid out to handle coils weighing up to 36 tons, in gauges from 0.020 in. to 0.120 in. thickness and up to 6 ft. 9 in. width, with strip speeds of up to 325 ft./min. All five shear lines are scheduled to go into operation early in 1962.

Schloemann are also supplying for the cold mill at the same works a plant for slitting and recoiling cold-rolled steel strip, in addition to a preparation line for tin strip.

NEW HEATING PLANT INSTALLED AT WILMOT BREEDEN FACTORY

WILMOT BREEDEN LTD. recently acquired a factory at Cheston Road, Aston, Birmingham, in order to launch an extensive manufacturing programme for Tru-flo stainless steel, light-wall fittings for the petroleum, chemical and nuclear processing industries and for the manufacture of Velflo circular duct fittings for high-velocity air-conditioning systems.

A medium pressure hot water system with a working pressure of 50 lb. per sq. in. will be used, which will have flow and return temperatures of 270° and 220° F respectively.

One economic boiler rated at 7 million B.T.U's. is to be installed along with a Brockhouse modulating oil burner. Fuel oil of 960 sec. viscosity will be used and will be stored in a 9,000 gal. tank.

Pressurization will be effected by means of compressed nitrogen gas, the plant consisting of the normal expansion vessel, spill tank and control panel.

A circulating pump rated at 220 gal. per min. against a frictional head of 25 ft. and a static head of 50 lb. per sq. in., will be incorporated in the system.

The system is designed and installed by Froggatt and Prior Ltd., of Birmingham.

A total of 60 Copperad unit heaters, each complete with electric motor, will be fitted throughout the building at heights varying between 9 and 15 ft. In addition, ten Copperad wall-type convectors will also be installed in the offices.

Iron and Steel Institute Bibliography

THE Iron and Steel Institute has prepared another extension to the Bibliography on "The Rolling of Iron and Steel" which first appeared as Bibliographical Series, No. 15, in 1948, and covered the period 1920 to 1947; the first extension, No. 15a, appeared in 1955 and dealt with 1948 to 1954.

The new extension, No. 15b, covers the period 1955 to 1960; it has been produced by off-set litho and photo-litho, and is available to members of The Iron and Steel Institute at 30s. 0d. and to others at 40s. 0d. It contains about 2,000 abstracts in 164 pages, a list of text books and BISRA reports, and is fully indexed by authors and companies.

Publications for Industry

Johnson Matthey and Co. Ltd., have issued a new series of data sheets describing their range of small-bore tubes and tube products. Tubes to fine limits are available principally in non-ferrous metals and alloys, although grades of nickel-iron alloy are supplied, as well as tubes in precious metals for specialized applications.

The data sheets describe Johnson Matthey tubes in terms of end uses, for example Bourdon tube, capillary tube, restrictor tube, instrument pointer tube, tube for applications in electronics, and miscellaneous base-metal tubes.

Sets of data sheets and further information are available on application to the company at 78-83 Hatton Garden, London, E.C.1.

* * *

The American Society for Testing Materials announces the availability of a 62-page list of publications. This describes the Symposiums, Manuals, Special Publications, Indexes, Compilation of Standards, Charts, Reference Photographs and Reports published by the Society through the years. More than 300 items are fully described, 40 of which are new and not previously listed.

The publications cover all phases of materials and their evaluations and are arranged conveniently by titles and subject. The list may be obtained free from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

* * *

A publication covering the selection of the most efficient materials for use in the handling equipment of the pickling process has been produced by Henry Wiggin and Co. Ltd.

Hot-working or other thermal treatment on metals frequently results in the formation of a surface layer of oxide, the removal of this layer by immersion in an acid or alkali solution is known as "pickling". The work to be pickled must be suspended in the solution in such a manner as to allow the acid or alkali free access to all surfaces, and the handling equipment must resist the corrosive attack of the pickling liquors.

The choice of material for the equipment and its design are the two aspects of the process on which this publication offers advice.

The publication, which is illustrated and contains many working drawings, is obtainable free on request from the Publicity Department, Henry Wiggin and Co. Ltd., Thames House, Millbank, London, S.W.1.

* * *

Something of the colourful background surrounding the production of the familiar angle iron, basic ingredient of the traditional iron bedstead, is revealed in "Angle on Production", an interesting article appearing in the July/September issue of *The Forge*, journal of the Brockhouse Organization. Another feature in this edition describes some of the problems connected with the provision of adequate braking on semi-trailers and gives details of some systems in current use.

Other items include a pictorial review of the Army's new Computer Centre at Worthy Down, built on the Brockhouse pre-fabricated steel structure system; news of Group activities at home and abroad and a report on the Organization's Annual Golf Tournament.

* * *

Associated Electrical Industries Ltd., has recently issued a new publication—"The AEI Arc Welding Guide"—which replaces previous Metrovick electrode guides.

In addition to the latest data on the wide range of AEI welding electrodes, this enlarged booklet contains a considerable amount of technical information on welding, providing a comprehensive guide for the welding fabricator.

Included in the new sections are a complete list of British Standard Specifications relating to welding processes and applications, notes on the care of electrodes, and a brief list of AEI arc-welding plant.

Copies of this publication, No. 1891-71, may be obtained free on request from Associated Electrical Industries Ltd., Heating and Welding Department, Trafford Park, Manchester 17, or any AEI District office.

* * *

A new brochure (P.1008) "Witton Kramer Electric Lifting Magnets", fully revised from an earlier one of the same title, is now available from The General Electric Co. Ltd., Witton, Birmingham, 6.

This 24-page publication includes the full technical details of the company's electric lifting magnets, together with descriptions of the associated control gear. It is profusely illustrated with drawings and photographs showing the construction of the magnets, and also includes pictures of the magnets in service.

* * *

The second report of the Export Council for Europe, because of the importance of its subject at the present time, is devoted wholly to *West Germany*.

An 8-man fact-finding team, drawn from members of the Council and led by Sir William McFadzean, its chairman, toured the chief industrial centres in West Germany in May. This pamphlet contains their principal findings and recommendations, together with illustrative statistics, not previously published, on different products.

In a message from the chairman, with which the report is introduced, Sir William McFadzean writes: "West Germany is a tremendously exciting and challenging market, particularly in the breadth of opportunity and the encouragement given to imports". Industry is booming, demanding more and more plant and mechanization and causing gaps which British firms might fill.

The German market is wide open to British exporters in a wide range of products. British exports to West Germany have trebled since 1955 and doubled since 1958 and, including re-exports, are now running at the rate of about £190 millions per annum. This still represents less than 5 per cent of Germany's present imports.

Copies of the report are available from Export Council for Europe, 21 Tothill Street, London, S.W.1, price 5s.

* * *

The second report of the Industrial Training Council covering the period from January, 1960 to March, 1961, is now available.

The report describes the work carried out by the I.T.C. during this period, which was mainly concerned with the steps taken by the Council to encourage industry, through employers' organizations and trade unions, to take full advantage of the "bulge" in school leavers by recruiting and training more skilled workers. The Council's work in this sphere has recently been extended by the appointment of regional committees to bring home its message at the local level. The report also indicates how the Council has started on its long-term task of helping to improve training arrangements throughout industry, and how the work of its Training Advisory Service has developed.

The report can be obtained from the offices of the Council, 36 Smith Square, London, S.W.1, price 1s. 3d. exclusive of postage.

NEW PLANT and EQUIPMENT

A monthly review of new machines, equipment, processes, etc., of interest to the producer and user of sheet metal

Furnace for Stainless-Steel Strip

TRUE bright annealing—*i.e.* annealing without any detriment to a bright, cold-rolled or drawn surface—has always been difficult for producers of stainless-steels and other chromium-containing alloys. Acceptable results have been obtainable in certain cases—*e.g.* wire and narrow, thin strip—by heating in a muffle purged with very pure hydrogen or nitrogen-hydrogen mixtures. This practice has the severe limitation of recurrent muffle repair or replacement costs and satisfactory muffles have not been available for any but narrow furnaces.

The research department of AEI-Birlec Ltd. have now produced a new furnace, needing no muffle, a prototype of which has been in operation for some months with highly satisfactory results.

Based on the use of a special type of refractory for the lining, this new furnace breaks through the limitations of the muffle type in several respects. The electric heating elements radiate directly onto the work without the intervening obstacle of the muffle wall, and therefore permit higher heat inputs and higher work temperatures than could be safely used in the old design. Means for conveying the material through the furnace are no longer limited to those which could be contained within a muffle. Furnace chamber size and shape is similarly freed from restrictions imposed by muffle design.

Furnaces of the new Birlec design therefore can be built in a wide variety of sizes and shapes to suit a range of products and processes. In all cases they are based on the continuous passage of the material since batch operation is impracticable by reason of the time required to establish in the work chamber a protective gas atmosphere of sufficient purity to give truly non-oxidizing conditions. In any case, the producers of sheet, strip, tube, etc., generally base their work on continuous operations, this being dictated by the metallurgical requirements of many of the materials concerned.

In its prototype form, the furnace is designed for the continuous bright annealing of strip which passes horizontally through the consecutive heating and cooling chambers. Special gas seals at the ends reduce the loss of atmosphere gas (cracked ammonia or hydrogen) to a minimum and rollers support the moving strip. A vertical version of the furnace is available for dealing with highly finished strip which must not come into contact with rollers or other supports while heated, but the horizontal type is adaptable to handle tubes or other forms of material on a moving belt or roller conveyor.

This new furnace (Fig. 1) offers advantages to producers of stainless alloys in the elimination of pickling and mechanical cleaning plant.

Further details can be obtained from AEI-Birlec Ltd., Tyburn Road, Erdington, Birmingham 24.

Fig. 1.—Furnace for stainless-steel strip

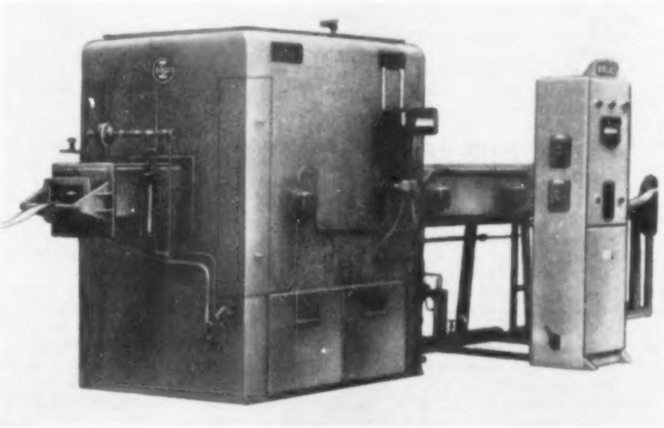


Fig. 2 (*left*).—*Powder container for spraying pistol*

Fig. 3 (*right*).—*Metal-spraying pistol in operation*

High Throughput Metal-spraying Pistol

RUST and scale are often removed at a high rate from heavy beams and plate in civil and constructional engineering, shipbuilding and general sheet-metal engineering by automatic grit-blasting. Spraying a zinc or aluminium coating on to the cleaned surfaces provides excellent protection from corrosion but normally requires a large labour force of sprayers to keep pace with the pre-treatment machines: the spraying speed of conventional wire and powder pistols cannot be increased by increasing the throughput of metals, since deposition efficiency then falls very considerably. The Model 61 metal spraying pistol has therefore been developed by the Coating Division of F. W. Berk and Co. Ltd., London, N.W.10, for an hourly throughput of 110 lb. of zinc at a deposition efficiency previously only achieved with low throughput guns: this throughput enables an area of approximately 450 sq. ft. to be given an 0.004 in. thick zinc coating, at a cost, including oxygen, propane, powder and labour, of about 4d. per sq. ft. The throughput is achieved by splitting the powder stream into four equal small streams and alternating these with gas streams. The gun weighs only 3 lb., and the gas, air and powder hoses all enter at the rear, thus giving good balance.

Since this gun does not require to be as versatile in spraying all types of metals at all speeds with various gases as with the conventional gun, the only control on the Model 61 gun is a spring-loaded trigger, operating remote valve controls for gas and air supplies: in this way, main supplies are cut off when the trigger is released and the gun cannot be laid down under spraying conditions. Powder for the gun is fed from an easily recharged 2-cwt. capacity container, a 1-cwt. drum of powder being tipped straight into it when required. The powder supply is cut off at the feeder when the trigger is released, preventing any build-up in the powder line to the gun and eliminating any wear on powder valves: the only parts subject to wear are the nozzles and the hoses feeding the material. As the powder feed unit is of fixed type, the operator is sure to work at the correct throughput in relation to the flame. A small box contains the controls, preset on final testing before despatch from the factory, and when first beginning to spray it is only necessary to open one cock and the compressed air supply is fed to the various air-operated valves ensuring that the correct volume, pressure and time sequence of air, gas, oxygen and powder is applied to the pistol.

Since the powder is split into four individual streams, each surrounded by a gas flame, the gases have only to heat a relatively small powder cross-section in each stream: as a result, less oxygen (only 95 cu. ft. per hr.) and less propane (only 27 cu. ft. per hr.) is used than with equipment giving a quarter of the output of the Model 61 gun. The gun's high throughput will in most cases allow the number of guns employed in existing installations to be halved. The coatings produced with this pistol are as fine and dense as those produced by a low-output gun and superior to those from any other relatively high output equipment. These coatings are ideally suited for the efficient and economic application of subsequent paint coatings if required.

Demonstrations of this new equipment can be arranged either at the company's works or on site.

Acrylic One-coat Finish

ARMACRYL, a new acrylic one-coat finish for metal products and equipment of all types, has been introduced by Griffiths Bros. and Co. London Ltd., Armour Works, Well Lane, Wednesfield, Staffs. The finish is said to be particularly suitable for the finishing of domestic appliances of all kinds, such as washing machines, refrigerators, electric cookers, food mixers, and all kitchen and bathroom products. Similarly it is ideal for sewing machine cases, panel heaters, electric fire casings and photographic processing dishes and equipment.

In the industrial products field there are many applications. Switch boxes, safes and equipment used in conditions of frequent condensation and high humidity can be finished in Armacryl to advantage.

Being resistant to staining and chemicals, ink and dyestuffs, it can be applied on operating theatre and general medical equipment, catering and food manufacturing appliances and machinery, chemical balances, bobbins, hosiery manufacturing machinery, photo-copying machines and oil burning plant.

(*Continued in page* 776)

The finish is especially valuable for application on products manufactured for export to tropical and semi-tropical climates.

The outstanding properties claimed for Armacryl are:

(1) Humidity resistance,
(2) hardness,
(3) resistance to colour change on heating, over stoving, or exposure to exterior weather conditions,
(4) chemical resistance,
(5) grease, stain, and detergent resistance,
(6) flexibility and impact resistance,
(7) adhesion.

These properties are all obtainable with a one-coat application on steel, without primer (which latter need only be used if the metal surface is poor and needs filling). The finish can also be applied directly to Zintec and the results are claimed to be superior to those usually obtained, but aluminium may require chemical pretreatment of the Alochrome type if the surface is highly polished.

Application can be by spraying or dipping, and stoving by convection should be for a minimum of 300° F. for 30 min.

Performance is improved by increased stoving at 350° F. for 45 min. Infra-red timings and temperatures vary according to the equipment used.

Welding Electrode

AN improved "Diadem" emerald electrode for use either as a "contact" or free arc electrode has been produced by Cooper and Turner Ltd., of Vulcan Road, Sheffield 9, for general-purpose welding on all thicknesses of mild steel from 14 s.w.g. upwards. The lighter gauges of this electrode may be used in all positions.

This electrode is claimed to produce fillet welds of mitre profile, a self-releasing slag, a wide current range and a stable soft arc and a high burn-off rate at normal currents.

The electrode is approved by the Ministry of Transport and Lloyds Register for welding in the down hand position on structures of primary importance and by the Admiralty and Ministry of Aviation E.I.D. for welding mild steel in the flat position. It complies with the requirements of B.S.639, Covered Electrodes for the Metal Arc Welding of Mild Steel, B.S.1856, General Requirements for the Metal Arc Welding of Mild Steel and B.S.2642, General Requirements for the Metal Arc Welding of Medium Tensile Weldable Structural Steels, B.S.968, Type "A"—High Tensile (fusion welding quality) Structural Steel for Bridges and general building construction.

The Emerald electrode is coded E.947 on the B.S.1719—1951 coding and E.6012 on the A.W.S.—A.S.T.M. designation. Mechanical properties of deposited metal include a yield point of 24/28 tons per sq. in. and an ultimate tensile strength of 29/34 tons per sq. in. Its elongation on 1.5 in. gauge length is 26/32 per cent, the reduction of area on 0.424 in. diameter being 40/50 per cent. The Charpy impact value is 40/60 ft.-lb. A chemical analysis of the weld metal is carbon 0.08-0.10 per cent, silicon 0.11-0.14 per cent, manganese 0.55-0.65 per cent, sulphur 0.025-0.035 per cent and phosphorus 0.015-0.025 per cent.

This new electrode is produced in a range of seven sizes from 12 gauge to 3/16 in. diameter. The deposition time per foot of electrode at maximum current ranges from 55 sec. at 12 gauge to 72 sec. at 6 gauge. Current values are 80 amp. average and 100 amp. maximum at 12 gauge and 195 amp. average and 235 maximum at 6 gauge. The production of fillet welds of mitre profile by contact welding with this electrode is reflected in the figures given for the weight of electrode required to deposit 100 ft. of fillet weld, these ranging from 7 lb. when the leg length is 1/8 in. through 22 lb. at 1/4 in. to 74 lb. at 1/2 in.

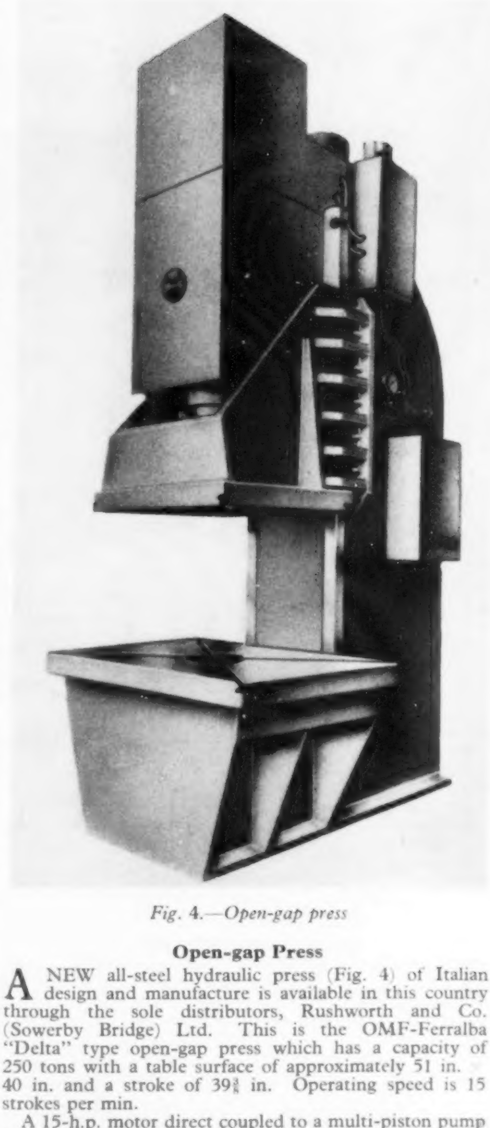


Fig. 4.—Open-gap press

Open-gap Press

A NEW all-steel hydraulic press (Fig. 4) of Italian design and manufacture is available in this country through the sole distributors, Rushworth and Co. (Sowerby Bridge) Ltd. This is the OMF-Ferralba "Delta" type open-gap press which has a capacity of 250 tons with a table surface of approximately 51 in. × 40 in. and a stroke of 39 3/8 in. Operating speed is 15 strokes per min.

A 15-h.p. motor direct coupled to a multi-piston pump operates the hydraulic system which is provided with an automatic valve for quick filling and discharging of the cylinder during idle strokes and also with an adjustable slide stopping device. Control is either by push-buttons mounted on the side of the upright which operate a servomotor or by a manual control lever. The slide can also be controlled by means of pendant push-buttons.

The maximum tonnage is exerted throughout the entire stroke and thus the necessity of vertical die adjustment is eliminated. A special feature of the design of the press is its delta shape which gives exceptionally

(*Continued in page* 778)

good accessibility to the table and greatly facilitates the handling of bulky workpieces. High precision has been ensured by the provision of large surfaces for both piston and slides, which by reducing friction minimise wear on these working parts. The slides are protected by a steel guard.

An interesting optional ancillary available for operation with this machine is an all-steel press brake attachment which provides a maximum folding length of 9 ft. 10 in. Other optional extras are ejectors and a blank holder under the table.

A smaller version of the same machine has a capacity of 150 tons and a table surface of 41 in. × 29 in. with a stroke of 27⅝ in. Speed of operation of this unit is 25 strokes per min. The folding attachment for this model has a maximum length of 6 ft. 7 in.

The advanced design, robust construction and high precision of the OMF-Ferralba press combine to produce rapid and accurate results in forming, bending, straightening, embossing, trimming, punching, deep drawing and extruding operations.

Further information may be obtained from the distributors at Sowerby Bridge, Yorkshire.

Plastic Putty

"TALURIT" plastic putty is a new material that is malleable and yet when formed sets rock hard. It is an efficient electrical insulator and can be machined, drilled, tapped or threaded. It has a wide range of uses, and is suitable, for example, for sealing cracks and holes in all types of hollow piping. In fact, its applications are limited only by the ingenuity of the user (Fig. 5).

This new plastic putty consists of two separate components—a resin and a hardener. When these two are completely integrated in equal proportions (which is easily effected in the hands), a readily workable putty is provided that will adhere to anything. It cures itself naturally in anything from 1½ to 18 hours according to the room temperature and remains dimensionally stable while at the same time attaining considerable hardness and strength, high electrical insulation qualities and exceptional resistance to oil, spirits and water. Independent tests from a number of representative samples provided the following results :

Compressive strength (ult.)	11,200 lb. per sq. in.
Tensile strength (ult.)	700 lb. per sq. in.
Dielectric strength	253 V/mil
Resistance between electrical conductors and armour	37,300 megohms
Resistance between electrical conductors and water	27,850 megohms
Water absorption	2.7 per cent

Available from Cable Covers Ltd., St. Stephen's House, Westminster, S.W.1.

Aid to Metal Spraying

THE use of metal spraying pistols having a high throughput of metal create new problems in the spraying technique. Pistols now available are capable of spraying zinc at the rate of 60 lb. and more, per hour and aluminium at equivalent coverage rates.

At such high delivery it is of great importance that the metal is applied with the utmost economy. For this reason Metallisation Ltd., Pear Tree Lane, Dudley, Worcs., after looking closely into this problem have produced an anxiliary spreader nozzle for attachment to their Mark 33 metal spraying pistol. This special attachment will spread the spray stream from a $\frac{3}{16}$ in. diameter wire to an effective width of 3 in. at normal spraying distance.

In extended trials the nozzle has proved of considerable advantage when coating large surface areas. The use of high throughput pistols for the spraying of small or complicated shapes is not recommended since the most economical and effective metal spraying depends largely upon selection of the most suitable size of wire.

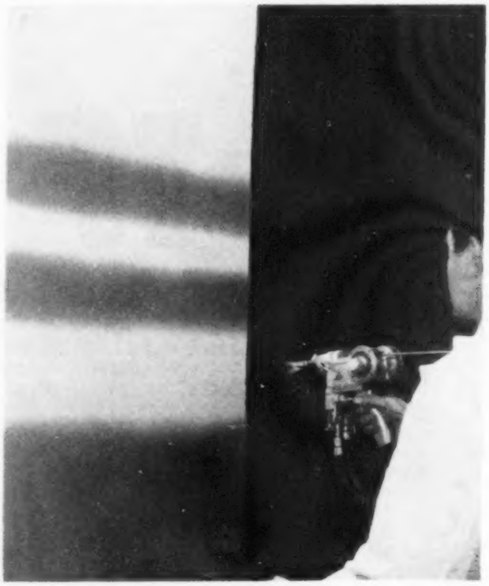
Modern pistols such as the Mark 33 are capable of using wires varying in diameter from 1 mm. to $\frac{3}{16}$ in. so that the selection of wire demands only the change of a nozzle. The new spreader attachment has an additional feature in that it may be switched on and off independently of the pistol. This is effected by means of a small tap situated at the base of the pistol.

Fig. 6 shows the coating deposited by one sweep of the gun under normal conditions, compared below with a deposit applied by the spreader nozzle. This auxiliary nozzle adds very little weight to the pistols and may be fitted in a few minutes.

Further information may be obtained from the company at the above address.

Fig. 5 (left).—Typical use of plastic putty

Fig. 6 (right).—Auxiliary spreader nozzle




W.R.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Advertisements (accompanied by a remittance) and REPLIES TO BOX NUMBERS should be addressed to the Classified Advertisement Manager, "Sheet Metal Industries," John Adam House, 17-19, John Adam Street, Adelphi, London, W.C.2. Telephone: TRAfalgar 6171.

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TIN BOX Plant and Presses required suitable for round and irregular containers manufacture.—Modern Packages Ltd., Byass Works, Port Talbot, Glamorgan.

BRAKE Press wanted, approx. 8 ft. 0 in. x 10 gauge. Price and particulars. Jenkins Fidgeon, Ltd., Linley Road, Talke, Staffs. Tel. Kidsgrove 2368.

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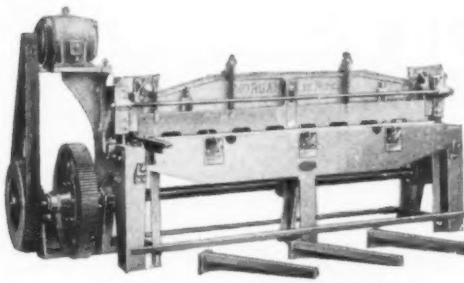


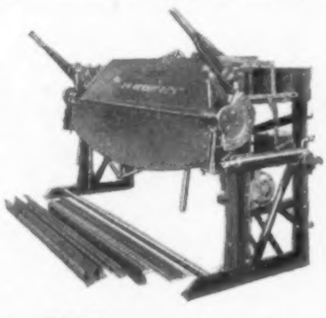
Guillotines

treadle

3' × 18G — £64.10.0
3' × 16G — £81. 0.0
4' × 18G — £94.10.0
4' × 16G — £105. 0.0
6' × 18G — £245. 5.0
8' × 20G — £344. 0.0

power

4' × 14G — £395.15.0
4' × 10G — £542. 5.0
6' × 14G — £535. 0.0
6' × 10G — £640.10.0
6' × 1/4" — £1,476.15.0
8' × 1/4" — £2,021. 5.0



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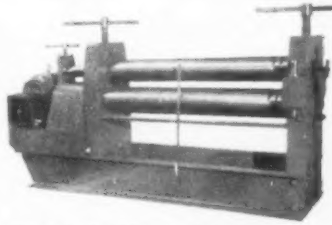
6' × 1/8" — £435. 0.0 (Drop End)
6' × 1/4" — £840. 0.0 (Drop End)
6' × 3/8" — £940. 0.0 (Drop End)
8' × 1/4" — £900. 0.0 (Drop End)
8' × 3/8" — £1,365.0.0
8' × 1/2" — £1,930.0.0



Folders

3' × 18G — £70. 0.0
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6' × 14G — £338.15.0
6' × 10G — £565.10.0
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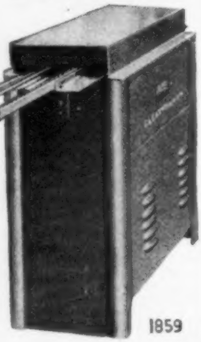

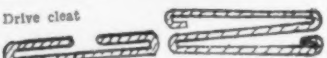

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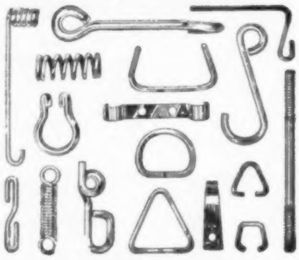

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